JOURNAL of the AMERICAN WELDING SOCIETY

Issued Monthly

Vol. 12
No. 2

FEBRUARY
1933

WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

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20th and Northampton Sts.
Easton, Pa.

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Subscription $5.00 per year in United States and possessions; $5.50 in Canada; Foreign Countries, $10.00; Foreign Libraries, $6.00.

Entered as second-class matter January 15, 1932, at the post office at Easton, Pa., under the Act of March 3, 1879.

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SOCIETY AND RELATED ACTIVITIES

Annual Meeting

The annual meeting of the Society will be held in New York on April 27th and 28th. There are to be several unique features of this meeting.

1. Members of the Society will be given every opportunity to discuss the business affairs of the Society including Section activities, membership, etc.
2. A special lecture on structural steel welding presenting a complete review of the knowledge on this subject.
3. Presentation of several important committee reports and their discussion.
4. The American Bureau of Welding and some of the research reports resulting from its investigational work.

Fall Meeting

Announcement was made at the recent meeting of the Executive Committee that the fall meeting of the Society will be held in Detroit the week of October 2nd in connection with the Metal Congress Exposition. Arrangements have already been started to make this meeting an outstanding one in the history of the Society.

Members of the Society desiring to present technical papers at the fall meeting are urged to send in these requests at once to Society headquarters.

Conference on Re-Engineering for Economical Manufacture

The Case School of Applied Science, Cleveland, has announced that it will be host for a conference on the above subject to be held on March 22, 23 and 24, 1933. Some 12 important papers are scheduled. Welding is to receive a prominent place on this program.

Power Exposition

The 6th Midwest Engineering and Power Exposition will be held during the week of June 25, 1933—Engineering Week—in Chicago during the World's Fair. Early indications point to a complete utilization of the 85,000 sq. ft. of floor space at the Coliseum Building with exhibits of machinery, equipments and supplies portraying the latest advances in the various wide uses of power, from ordinary power operated tools to large generators, engines, pumps, heating and air conditioning and many others of like importance.

F. J. King Elected President of Compressed Gas Manufacturers' Association

F. J. King, Chief Engineer of The Linde Air Products Company, was elected President of the Compressed Gas Manufacturers' Association at the Annual Meeting held at the Waldorf-Astoria in New York, January 23 and 24, 1933.

This election marks another recognition of Mr. King's outstanding contributions to technical progress in the compressed gas industry. Shortly after graduation from the Massachusetts Institute of Technology in 1909 Mr. King became affiliated with The Linde Air Products Company as Junior Engineer. He has been closely identified with the manufacture of oxygen and acetylene and the development of their applications, particularly in the expanding use of the oxy-acetylene welding and cutting process.

F. J. King

Great Engineering Gathering at Chicago

What promises to be the greatest and most important conference of engineers ever held in this country, and probably the world, will convene in Chicago during the week of June 25–30th in connection with A Century of Progress Exposition. World's Fair officials have designated this period as "Engineering Week," and one day will be known as "Engineers' Day."

Early estimates of the probable attendance of engineers from all parts of the country, as well as from many European countries, place the figure at a minimum of 25,000 with a possibility of triple that number.

A general committee known as the Engineering Societies' Committee of A Century of Progress Exposition has already been established in Chicago under the chairmanship of Harry B. Gear. Organization work is now under way and a number of sub-committees have been appointed to function on the various phases of the coming event.

The plan is for the various societies to hold individual or joint meetings of their own groups except for "Engineers' Day" when all groups will join in a giant conference.

The outstanding engineers of this and other countries will appear on the program to report the newest developments in their respective fields.

Coincident with the speaking program there will be held an exposition of power and engineering machinery and appliances in keeping with the size and importance of the gathering.

Approval of participation has already been given by 19 engineering associations, either by their national headquarters, or through their Chicago chapters. Others will also participate. The organizations cooperating are as follows:

American Association of Engineers
American Ceramic Society
American Foundrymen's Association
American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Municipal Engineers
American Society of Testing Materials
American Society of Agricultural Engineers
National Council of State Boards of Engineering Examiners
Society for the Promotion of Engineering Education
Society of Industrial Engineers
Institute of Radio Engineers
Western Society of Engineers
American Institute of Architects
American Society of Heating & Ventilating Engineers
American Society of Refrigerating Engineers
National Association of Practical Refrigerating Engineers

The general public little realizes the tremendous part played by the engineering profession in making life more comfortable, in lifting the burden of manual labor for all members of the household and of the multitude of other benefits which have played such a vital part in the advancement of civilization. It is felt that the coming week of meetings, conferences and exhibits provides an ideal opportunity to demonstrate what the engineering profession means to humanity.

G. E. Pfisterer, Chairman of Publicity, Joint Committee of Engrg. Societies, A Century of Progress Exposition.

Section Activities

BOSTON

The January meeting was held on Friday evening, the 20th, at the Massachusetts Institute of Technology. Mr. W. H. Ludington, Manager of the Applied Engineering Department of the Air Reduction Sales Company, New York, gave an interesting illustrated talk on "Railroad Car and Locomotive Scrapping." He described the methods used in the process of scrapping this obsolete equipment, discussed the economies of the proposition and showed how oxyacetylene cutting was particularly useful in this work. After Mr. Ludington's talk, the meeting was open for discussion.

On February 17th, the Boston Section will hold its regular meeting at 7:30 P.M. in the rooms of the Engineering Societies of Boston, 715 Tremont Temple, and the following interesting program will be presented: "Structural Welding, as Provided in Building Codes"—speaker, J. T. Whitney, Whitney Engineering Co., Boston. "The All-Welded Pediatric Building of the Boston City Hospital"—speaker, A. S. Coombs, Whitney Engineering Co., Boston.

The Massachusetts Department of Education will offer a University Extension Course on the subject of Welding Engineering. The course is offered in cooperation with the AMERICAN WELDING SOCIETY, Boston Section, and will consist of eight lessons, the first being on Thursday evening, February 2nd, at 7:30 P.M. at the Massachusetts Institute of Technology. Mr. H. R. Bullock, Department of Mechanical Engineering, M. I. T., is the instructor for the course. Mr. Bullock is a member of the Fundamental Research Committee, American Bureau of Welding. A charge of $5.00 is made for each person taking the course.

The subjects of the course include: types of welding; kinds of welds and their proper application; fusion welding of steel, cast iron, aluminum, brass and bronze by the oxyacetylene process, with a description of the use of the apparatus; gas cutting of iron and steel; arc welding of steel, cast iron and aluminum with the atomic arc, shielded arc, fluxed electrodes, manganese electrodes, alloy steel electrodes, carbon arc, automatic arc and the apparatus used; metallurgy and metallography of welding, covering equilibrium diagrams, cooling curves, solid solutions, iron carbon diagram, analysis of welded joints from macro and micro structure, porosity; design and strength of butt, lap and strap joints; industrial welding on pipes, pressure vessels, structural steel, airplane parts, machine frames, automobile parts, ship building; analysis of typical shop and field problems.

CLEVELAND

A real instructive and interesting Cleveland Section Meeting was held on Wednesday evening, February 8th, in the society rooms in the Hanna Building at 8:00 sharp.

The speaker was Mr. A. G. Leake, President, Leake and Nelson Co., who spoke on "The Welding of Structural Steel." Slides were used to illustrate many interesting points.

Admission to the meeting was by ticket only.

LOS ANGELES

The election of officers of the Los Angeles Section was scheduled for the January meeting.

At the meeting on December 1st, Mr. G. T. Brooke, Manager Industrial Division, Crane Company, gave an interesting lecture on the welding of industrial piping, showing the advantages of welding and how it had replaced other processes in pipe installation. Pictures were shown of several welded objects.

Mr. J. W. Krausser, Engr., Procter & Gamble Co., gave some interesting welding experiences of his Company.

Mr. L. I. Blennerhassett, C. F. Braun Corp., and Mr. Jahn, Midwest Piping & Supply Co., presented some interesting data on refinery piping.

Some very interesting data were presented by the Los Angeles Section in their Annual Report. The finances are in excellent shape with a balance in the bank of $106.25. The average cost per meeting has been exceptionally low, amounting to some $11.00. Some of the subjects covered at the meetings of the Section are: Welding Stainless Steels, Resistance Welding, Aircraft Fuselage and Aluminum Tank Welding, General Objectives of Vocational Training, Southern Fuel Pipe-Line from Kettleman Hills to Long Beach, Inspection and Tests of Welding in Structures, Fabrication of Steel Shapes by Use of Mechanical Gas Cutting and Arc Welding, Design and Construction of Arc-Welded Naval Auxiliary Vessel, Arc-Welded Steel Penstock, Metal Spraying and the Influence upon Welding, Welding Brass, Bronze and Their Alloys, Welding Aluminum and Aluminum Alloys and Welding of Industrial Piping.

The average attendance has been fifty.

PHILADELPHIA

The January meeting held on the 16th was quite successful, with about a hundred attending.

Mr. John J. Crowe of the Air Reduction Sales Company talked on "Testing of Welds" and illustrated his talk with lantern slides. He had with him a number of testing machines on which he gave practical demonstrations. After he had presented his paper, there was a very interesting discussion.

The subject "Gas Welding" has been selected for the February meeting.

The American Society of Heating and Ventilating Engineers extended an invitation to the members of the Philadelphia Section, AMERICAN WELDING SOCIETY, to attend its meeting on Thursday, Feb. 9th. This meeting was devoted to welding problems, both in gas and electric welding, and was addressed by the following gentlemen: Mr. Robert Daniels, General Electric Co., "Arc Welding Pipe," and Mr. Fred J. Maeurer, Air Reduction Sales Company, "Economic Advantages of Welded Piping in Homes." Both papers were illustrated by lantern slides.

PITTSBURGH

Arthur E. Christen, Pipe Welding Consultant, Toledo, Ohio, and Herbert P. Smith, Welding Engineer of The Herbert P. Smith Company, Pittsburgh, Pa., each presented an interesting paper on pipe welding within buildings at the January meeting of the Pittsburgh Section of the AMERICAN WELDING SOCIETY held the night of the eleventh at the Fort Pitt Hotel.

Mr. Christen, in his paper on "A Survey of Pipe Welding within Buildings," gave his views as to what steps should be taken to further the application of welding as a process for joining pipes within buildings.

"Stress Data Concerning Branch Connections of Welded Piping" was the subject of Mr. Smith's paper in which he presented test data taken from a report compiled by an oil company. The data presented showed that the ultimate strength of welding branch connections into the run of pipe is equal to and in most cases greater than that of the parent metal.

PORTLAND

The Portland Section met on January 24th at the Multnomah Hotel. After the official business of the Section was taken care of, Mr. R. C. Cooper, Sales Engineer with the Westinghouse Electric and Manufacturing Co., presented a paper entitled, "The Webster Truss Simplifies Building," which was a discussion of a new design in a welded building truss as advanced by the Westinghouse Co. His talk was illustrated by slides and blackboard.

The November meeting was held on Tuesday evening, the 29th. Mr. A. G. Bissell of Seattle, presented a paper on "Arc Welding to Save Weight in Bascule Bridge Reconstruction." The paper had direct reference to the reconstruction of the University Bridge in Seattle. Mr. Bissell had secured from the City Engineering Department, Seattle, a series of progress pictures which he showed on the screen by means of a balopticon. Mr. Bissell's paper, as well as the pictures, were of great interest to the members. Discussion followed presentation of the paper.

SAN FRANCISCO

The January meeting held on the 27th was given over to a discussion of metal spraying. Mr. William M. Moody, of the Heat Treating and Nitriding Co., Oakland, Calif., spoke on "Metal Spraying." Various types of metal spray guns were shown and the particular features of each were discussed, together with a general discussion of the various applications in which metal spraying is being used in industry today.

Mr. E. L. Mathy, Vice-President of Victor Equipment Company, Mr. Geo. C. Stoddard, Industrial Department, De Laval Pacific Company and Mr. W. A. Lortz, Agent for Dr. M. U. Shoop, discussed and displayed the various types of guns sold by their respective companies.

Economic Advantages of Welded Piping in Homes

By **FRED J. MAEURER**

†Paper presented at 33d Annual Meeting, International Acetylene Association, Philadelphia, Pa., November 16, 17 and 18, 1932, by Fred J. Maeurer, of the Air Reduction Sales Co.

TO CHANGE a present method of manufacture, construction or fabrication to that of another method the reasons for such change must be based on sound, proved fundamentals, agreeable and beneficial to all involved, or no change should be made.

In developing reasons for changing the present method of pipe fabrication in heating installations in the homes, which at present is by threaded fittings and threaded pipe, to the more modern method of oxyacetylene welding and cutting, it has been found and proved that sound fundamentals for this change do exist.

In submitting reasons for suggesting a change, we feel they must be such that the benefits resulting will be advantageous to every one or group connected with the (1) planning, (2) putting of the plans into effect and (3) the ultimate user of finished product.

In a piping installation the above three groups would be: (1) the architect, who plans the installation so that he is assured that it is correct in every detail, will operate efficiently and economically and is best for his client, (2) the heating contractor, who must be assured that the piping installation will be better than the previous method used, that he isn't penalized with additional costs and that it operates efficiently and economically, and (3) the ultimate user or home owner, who must be assured that his piping installation will be enduring, have small maintenance cost, have minimum friction losses, that he can deliver steam within the pipe to its objective at the least possible cost, in other words, that he will use the least amount of fuel to operate it efficiently and economically.

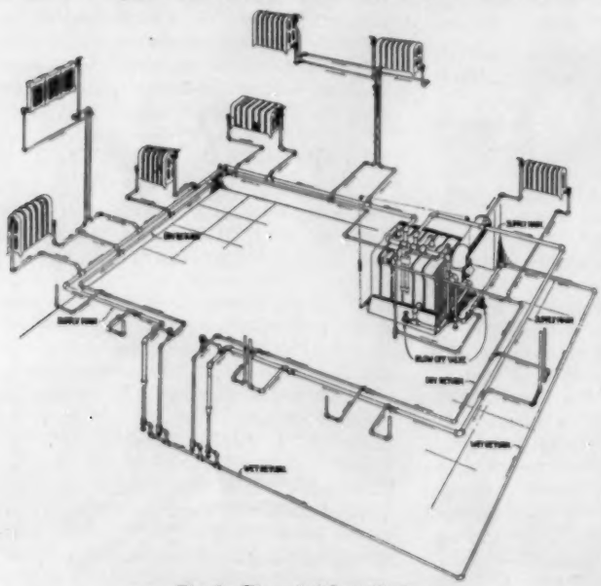


Fig. 1—Threaded Installation

MATERIAL LIST

NO. REQD	DESCRIPTION	COST
5	LIN. FT. 2½" STANDARD BLACK IRON PIPE	
120	" 2"	
210	" 1¼"	$ 55.28
110	" 1"	
110	" ¾"	
3	2½" - 90° C.I. ELL	
17	2" "	
32	1¼" "	
30	1" "	
30	¾" "	
4	1¼" - 45° "	
9	1" "	
5	¾" "	
3	1¼" TO 1" - 90° C.I. REDUCING ELL.	
4	1" - ¾" "	
1	2½" X 2½" X 2½" STD. C.I. TEE.	
1	2" X 2" X 2" "	
7	1¼" X 1¼" X 1¼" "	
2	1" X 1" X 1" "	
2	¾" X ¾" X ¾" "	
2	2½" X 2½" X 2" - REDUCING TEE	36.15
3	2" X 2" X 1¼" "	
9	2" X 2" X 1" "	
6	1¼" X 1¼" X 1" "	
5	1¼" X 1¼" X ¾" "	
1	1" X 1" X ¾" "	
2	2" TO 1¼" M.I. REDUCER	
6	1¼" M.I. PIPE CAPS.	
6	2" X 6" BLACK WROUGHT NIPPLE	
10	1¼" X 6" "	
6	1¼" X 3" "	
19	1" X 6" "	
11	¾" X 6" "	
2	2½" CL "	
4	1¼" "	
1	CAN RED LEAD	.85
	85% MAGNESIA INSULATION.	243.24
	TOTAL	$339.52

THREADED.

Fig. 2—Table of Costs for Threaded Installations

Now it is possible, with welding, to give each one of these three groups an easily planned, readily fabricated, efficient piping installation and that was not possible before the advent of the oxyacetylene welding and cutting processes, which, on top of it all, brings to each group economies that are not possible with the old method of threaded fittings and threaded pipe.

For the architect, welded pipe now brings true his dream of smooth interior of pipe throughout the entire piping installation, long sweep bends, less heat losses, smaller pipe sizes, less weight, flexibility, ease of changes without affecting plans and the best possible installation for his client. These advantages were not open or possible for him heretofore. The advantages of long sweep bends are very important at this particular time because they are being heavily stressed on piping of larger sizes, particularly on power piping installations.

To the heating contractor the welding of smaller pipe sizes in home piping installations offers very definite economies not available with the older method of threaded fittings and threaded pipe. With the welding of pipe he finds economies in labor costs, material costs, insulation costs and, what is far more important, a better and more enduring piping installation for the owner of the home.

To the home owner or ultimate user there comes for the first time the possession of a heating installation that meets with his demands, and he soon finds that a welded piping installation offers very definite economies for him not before possible.

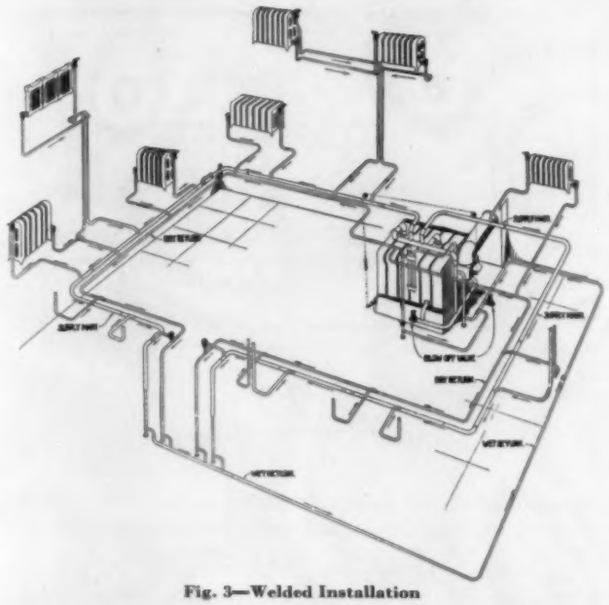


Fig. 3—Welded Installation

With smooth interior and exterior of his welded piping and long sweep bends he finds that his friction losses are reduced to a minimum, that the magnesia insulation can be perfectly fitted on the smooth outside of welded pipe, that he eliminates costly heat losses, that he can carry a boiler temperature of from 5 to 15 deg. lower than is necessary with threaded fittings and threaded pipe and that he is delivering the steam within the pipe to its objective at the least possible cost. All of this means to him lower fuel bills. He has a permanent piping installation with least possible number of joints and one whose maintenance costs are reduced to a minimum.

So, in suggesting a change in this particular piping fabrication, we have endeavored to show that there are ample reasons as to why the change should be made and to indicate some of the benefits that will accrue to all interested—meaning architect, contractor and home owner—that will guide them in promoting this change in heating and piping practice.

Figure 1 (Piping Installation—Threaded) shows a typical piping installation fabricated by the old method of threaded fittings and threaded pipe. This installation contains 242 threaded fittings and definitely shows short sharp bends at each joint that naturally set up heavy friction losses and involve much cutting and threading of pipe.

Figure 2 (Table of Costs for Fig. 1) lists all material costs of this piping installation but *does not include labor costs*. All material costs were received from National Companies after submitting blue-prints of installation for estimates, and all prices are net.

Figure 3 (Welded Piping Installation) is the same type of piping installation as in Fig. 1 but shows all joints welded and using long sweep bends. In this entire welded installation we use thirteen (13) welding fittings and use, wherever possible, long sweep bends by bending pipe on the job or in the shop, thereby eliminating fittings of any kind wherever possible.

Figure 4 (Table of Costs for Fig. 3) lists all material costs of this welded installation but *does not include labor costs*. All material costs were received from National Companies after submitting blue-prints of installation for estimates and all prices are *net*.

The total material cost savings for the welded long sweep bend installation is 10.3 per cent but this does not by any means represent the total savings possible because there is a very substantial saving to be had in the labor necessary for this and similar type of welded pipe installations.

We would like to state at this time that the type of piping installation shown in Figs. 1 and 3 was submitted to three National heating engineers and three prominent plumbing and heating contractors for their opinions on accuracy and practicability for both design and method of installation and received from them their indorsement.

A close study of the method of installing the welded installation (Fig. 3) will show that, outside of the header on the boiler, no welding fittings are specified and all changes of direction in piping call for long sweep bends made by bending the pipe either in the shop before being sent to the job or bent right on the job.

This bending is not only possible but is practicable. In the smaller size pipe, bending can be done cold and in larger size pipe it can be quickly heated by the oxy-acetylene flame and then slowly bent to desired angle. In the smaller size pipe bending can be readily accomplished by inserting smaller pipe in a pipe of larger diameter, then bent to desired angle and in the larger size pipe a pipe vise can be used to hold pipe while heating and bending is taking place.

It is highly probable, and we make the prediction that in the not far distant future, piping installations such as we show in Fig. 3 will be entirely fabricated in the shop, taken to job and assembled along the same lines as followed in bridge construction and other types of fabrication.

In a piping installation in small homes where smaller pipe sizes are used it is necessary to do a great amount of cutting and threading to complete fabrication, and all this cutting and threading means a threaded fitting of some kind must be used to continue the line of pipe. Following along this line of thought it becomes obvious that the greater the number of threaded fittings used in fabrication, the greater the amount of friction set up and the greater the amount of fuel which must be used to bring steam within the pipe to its objective.

To pursue this line of thought further it naturally becomes obvious that in a pipe installation with the least amount of obstructions in its fabrication, the smaller number of short radius bends and the greater number of long sweep bends, such as are obtained by bending long lengths, the least amount of fuel is consumed to deliver steam within the pipe to its objective. We are assuming the same size pipe is being used in both installations.

Now we have stressed friction losses, because it is important and because friction loss in small pipe sizes has not been given the attention it warrants. Previously nothing could be done about it outside of using larger pipe sizes to compensate the losses due to sharp bends and fittings as there was no other way of joining pipe

MATERIAL LIST

NO REQD	DESCRIPTION	COST
5	LIN FT 2½" STANDARD BLACK IRON PIPE	
120	" 2" " " " "	
210	" 1¼" " " " "	$53.65
110	" 1" " " " "	
110	" ¾" " " " "	
4	2½" 90° WELDING ELL	
2	2" 90° " "	9.38
1	2½" TO 2" " REDUCER	
6	1¼" M.I. PIPE CAPS, SCREWED.	
	ACETYLENE, OXYGEN & WELDING ROD	9.60
	85% MAGNESIA INSULATION	228.43
	TOTAL	$301.06

PLAIN ENDS

Fig. 4—Table of Costs for Welded Installation

together than by using the same old threaded fittings and threaded pipe. The advent of oxyacetylene welding and cutting has very definitely changed this view and practice because with welded piping and long sweep bends in an installation it has been definitely proved that it was not necessary to increase pipe sizes to overcome friction losses but that pipe sizes could be reduced.

To fully illustrate the friction losses that are set up in an all threaded fitting and threaded piping installation and to clearly show what we have said about the smooth interior and exterior of welded joints and long sweep bends that reduce friction losses, Fig. 5 shows one important section of piping that leads from the supply line to radiator.

The top section shows three views of a threaded fitting and threaded pipe fabrication that very clearly shows the short angle bends and the roughness on inside of pipe at the joint.

The lower section shows the same three views of the same fabrication that is welded, with long sweep bends used as described above; and it can be readily noted that there is nothing to retard the progress of steam to radiator. In the threaded fitting (threaded pipe views shown at the top) it is noted that four threaded fittings are necessary to complete the pipe run from main to radiator; that are welded, only two joints are necessary, the weld on the riser and one pipe weld as shown.

Because of the importance of insulation to a heating installation, blue-prints of Figs. 1 and 3 were submitted to a large National Company which specializes in insulation materials for bids on cost of insulation material.

Their heating engineers recommend that an 85 per cent magnesia material be used and quoted a figure of $243.24 for material cost of 499 ft. of straight insulation and 178 fitting joints for the threaded fittings and threaded pipe fabrication as shown on Fig. 1.

They then quoted a figure of $228.43 for 501 ft. of straight insulation and 138 fitting joints for the welded long sweep bend fabrication as shown on Fig. 3.

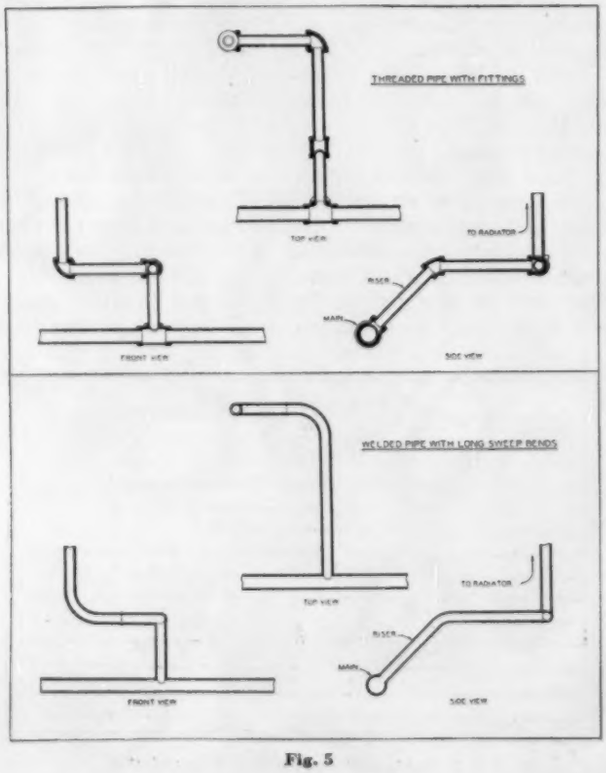


Fig. 5

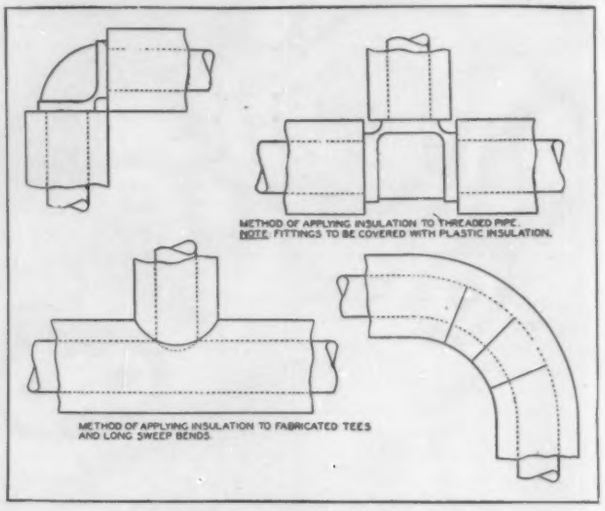

METHOD OF APPLYING INSULATION TO THREADED PIPE.
NOTE FITTINGS TO BE COVERED WITH PLASTIC INSULATION.
METHOD OF APPLYING INSULATION TO FABRICATED TEES AND LONG SWEEP BENDS

Fig. 6—Piping Installation—Threaded

While the estimate for insulating the welded long sweep bend fabrication was $14.81 lower than the estimate for the threaded fitting, threaded pipe fabrication, this does not show the entire saving that can be had because the cost of labor is not included.

Figure 6 clearly indicates where the real saving is made. On the threaded fitting, threaded pipe fabrication there are 178 joints that make it necessary to stop straight insulation forms at threaded fitting. In the case of an elbow, straight forms stop on both sides and the threaded elbow is then covered by plastic insulation and molded to same size as straight forms and then covered. In the case of a threaded tee and threaded pipe, straight insulation is brought up to the three sides of tee and plastic insulation is molded to same size of straight forms and covered.

This molding operation consumes much time that does not show in estimate of insulation costs but must be taken into consideration.

On the welded, long sweep bend fabrication it was estimated that there were only 138 joints that required plastic insulation operations and then only on the pipe bends of the smallest size pipe, and that 50 per cent of these joints could be efficiently insulated by cutting out sections from sides of straight forms, then drawn up, cemented and covered, as also shown on Fig. 6.

On all welded connections requiring a tee, straight forms can be exclusively used, eliminating plastic insulation by cutting a hole in top of one straight form and cutting the end of another straight form to fit. (Also shown on Fig. 6.) All these insulation savings are only possible on piping installations of oxyacetylene welding and cutting fabrication.

Much research work has been done on welded pipe fabrication for the heating contractor. Specifications and qualification tests have been developed by responsible engineers and the National Association and vocational schools in every section of the country have installed pipe welding classes for plumbers and steam-fitters where the fundamentals of welding can be correctly and economically learned. Technical papers on pipe fabrication have been written and published and large National threaded fitting companies and other large piping companies now have on the market welding fittings for welded pipe fabrication that meet any type of joint or change of direction of pipe that is necessary to be made, and all this means that the heating contractor who still fights shy of welding certainly is not taking advantage of the possibilities before him.

A Special River-Sea Bulk Cargo Arc-Welded Ship*

By GUSTAV F. D. WAHL *and* HARRY E. JOHNS

✦Gustav F. D. Wahl, Chief Naval Architect, and Harry E. Johns, Consulting Engineer, are with the Deutsche Werke Kiel Aktiengesellschaft, Kiel, Germany.

A PROPOSED arc-welded vessel for use in shipping coal from the Ruhr district to foreign European parts threatens to upset many of the old rules of naval architects. The ship was designed by the Deutsche Werke Aktiengesellschaft of Kiel, builders of numerous welded ships, the most prominent being the "pocket" battleship, *Deutschland*.

In the past coal was loaded in shallow draft vessels at river parts in the Ruhr and carried from there to a seaport where the cargo was transshipped to seagoing vessels. Such handling increased freight charges and lowered the quality of the cargo. The problem was to design a vessel to resist the hard wear of heavy seas, yet navigable in shallow river channels and withal large and fast enough for easy rentability. Experience has shown that vessels with a capacity of less than 2600 tons were not economical.

Were it not for the shallow draft and clearance under low bridges required, such a vessel would present no problems to naval architects who are governed by established proportions of length, breadth, draft and height above water. Difficulties of construction, however, increase when unusual proportions are adopted. When such unusual ships are built they are subjected to excessive strains in longitudinal connections if the established proportions of length to molded depth are violated. Furthermore, the proportion of breadth to draft governs the ability to resist strains to transverse connections in short rolling seas.

Based on established rules, a vessel designed for general cargo use for river-sea use would have a capacity of but 1700 tons, entirely too low to be practical for coal carrying. An abnormally proportioned boat of 2600 tons built by riveting would be useless because rivets work loose in heavy seas.

Considering the various factors involved, a vessel with the following specifications was necessary:

Length	299 ft. 4 in.
Breadth	42 ft.
Molded depth	17 ft. 7 in.
Draft	13 ft. 1 in.
Minimum speed	9.5 knots
Cargo capacity	2650 tons

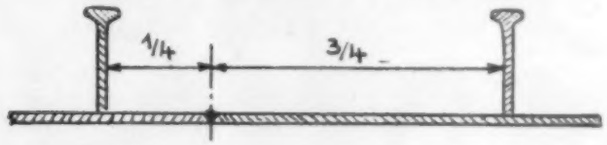
Suitable water ballast tanks would be required and the center of gravity for cargo and ballast should be so designed that sudden movements and dangerous jerks at sea would be eliminated.

Riveting was useless for a vessel of this type and the Deutsche Werke with the results of German Navy plate welding tests available decided upon welded construction at all points where stresses and strains were present. These welding tests proved that a welded joint in ship construction was 20 to 25% stronger than a riveted connection.

To compensate for the excess of length to molded depth and to make the vessel seaworthy, a longitudinal bulkhead for about $^3/_4$ of the ship's length was provided for at each side, forming a strong girder of box-shaped section. Longitudinal strength was further increased by trunk erection on the quarter-deck. To improve stability and to sink the vessel deep enough in ballast and for convenient trimming, ballast is placed at the sides of the ship, in top side wing tanks, in fore and aft peak and in deck tanks. By this arrangement the center of gravity of the cargo is raised, thus improving the seagoing qualities of this comparatively large beamed vessel. Figure 1 shows the wing tanks on the starboard side.

* This is a "brief" of a paper submitted for the Second Lincoln Arc-Welding Contest and was awarded Fourth Prize of $750.00. This contest was sponsored by The Lincoln Electric Company, Cleveland, Ohio. The judges of the contest consisted of the members of the Electrical Engineering Department of the Ohio State University, Columbus, under the chairmanship of E. E. Dreese, Head of the Department. The prize-winning papers will be printed complete in book form later.

Fig. 2—Bending Action Is Less at a Point One-Quarter the Distance between Frames, and Butts Are Located There



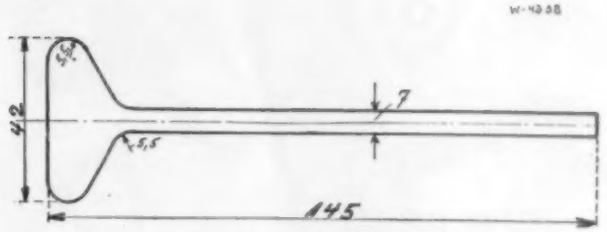


Fig. 3—Special Bulb Bar Specified

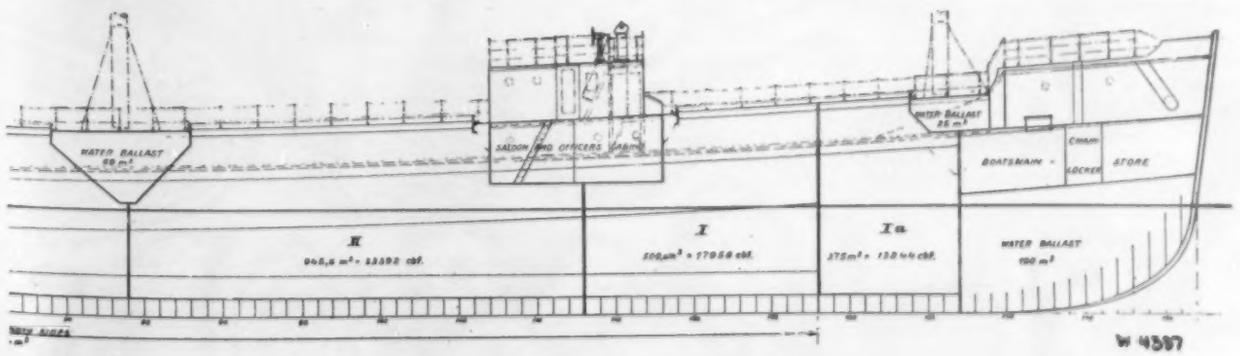


Fig. 1—Part of the Ballast Is Stored in Wing Tanks as Shown Here

All butts of shell plating, deck, longitudinal bulkheads and strength connections are to be welded. Longitudinal seams will be partially riveted to facilitate erection.

Detailed construction is as follows: The bottom plating consists of a single broad strake amidships in range of the parallel part of the hull, by which arrangement each plate is 4 frame spaces long. Side plating will consist of strakes 4 frame spaces long, extending from sheer-strake to bilge-strake. Plates of the sheer-strake, bilge-strake and flat keel will be 12 frame spaces long, as will the plates of deck stringer and longitudinal bulkheads.

Butts are placed where the least bending action takes place and where the plate is subjected only to tensile strain or pressure. This point was located about one quarter the distance from a frame, as shown in Fig. 2. Butts are welded as shown with an extra large bead on the inside of the vessel.

Instead of angles and other structural shapes used in riveted construction, a special bulb bar, as shown in Fig. 3, will be used. Experience has shown this shape to be ideal for welded fabrication.

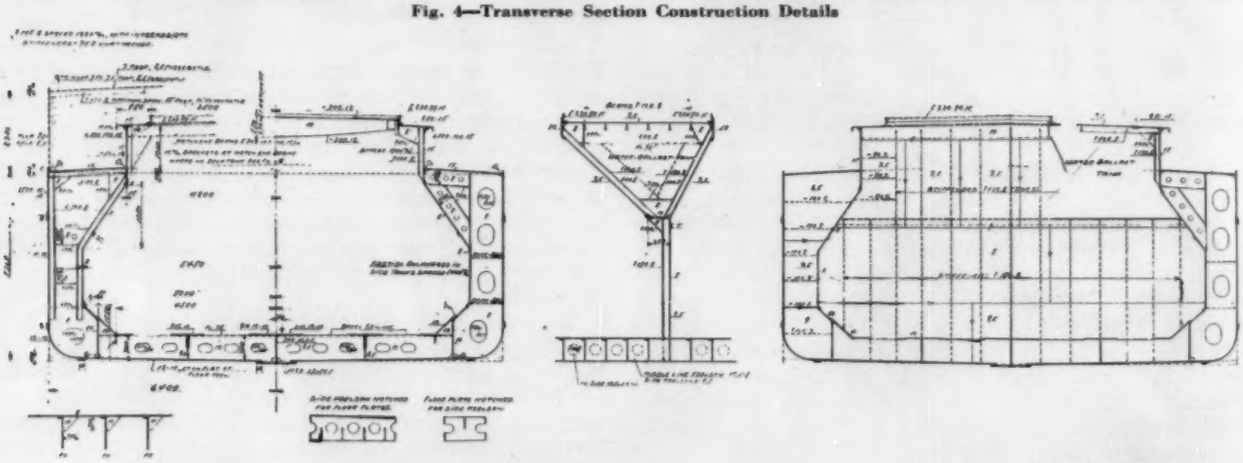
Construction on other arc-welded ships demonstrated that it is most economical to use a maximum of shop assembly, later moving the completed sections to the ways for fabrication. In the case of the vessel under consideration here, transverse bulkheads, side tanks, frames, strengthening web frames and numerous other parts will be shop fabricated. This method eliminates much overhead welding. Sections comprising 12 half floors of each side, together with the necessary plating, will be shop welded and moved to the ways as a unit. To build by this method the horizontal center keelson top plate will be cut longitudinally and the seam arc welded after the bottom sections at port and starboard have been fixed permanently.

Shop fabrication will also include the welding of 4 plates of the large bottom and side shell plates to a single large bottom shell plate and side shell plate into a unit which will later be placed in position on the ways.

The erection of the parallel part of the vessel amidships will be done as follows:

1. Flat keel to be laid and butts to be welded.
2. Large bottom plates, extending from bilge-strake to flat keel, to be laid on ways, to be connected by screws to flat keel and butts to be welded at every fourth plate.
3. Bilge-strake to be attached to landing edge of bottom plating by screws and bilge-strake butts to be welded.
4. Sections of bottom connections, welded in workshop, to be placed in position and temporarily fastened by tack welding where necessary.
5. Longitudinal seam of center keelson top plate to be welded up and butts of bottom keelson plates and top plates of those keelsons to be welded at butts, likewise the butts of lowest strake of side tank plating.
6. Transverse bulkheads in holds and side ballast

Fig. 4—Transverse Section Construction Details



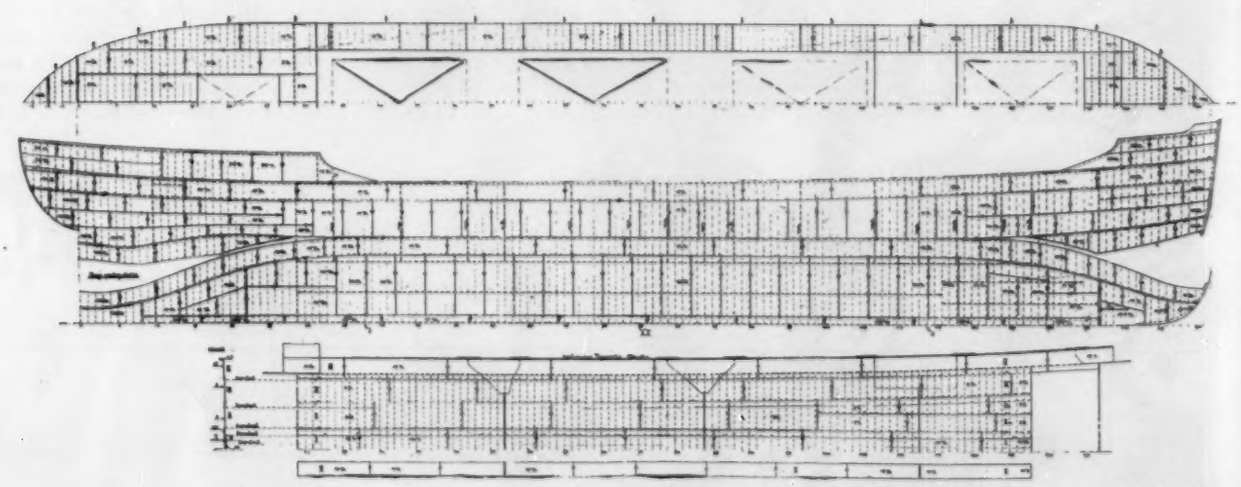


Fig. 5—Main-Deck, Shell and Longitudinal Bulkhead Details

tanks, likewise strengthened web frames and ordinary web frames to be erected.

7. Longitudinal bulkheads of side tanks to be erected, all seams to be screwed up and butts of those bulkheads as well as those of trunk sides to be tacked.

8. Inclined thwartships bulkheads for deck tanks to be attached to side tank plating and to trunk side plating.

9. Main-deck stringer plate to be placed on board.

10. Main-deck stringer plate to be attached to trunk side plating.

11. The large plates for ship's side shell, each consisting of 4 plates, with butts welded in workshop, to be put in place and butts to be attached by tack welding.

12. Sheer-strake to be taken on board and butts to be attached by tack welding.

13. All parts to be taken on board to be lined out fairly and all welding work of parallel part of vessel (that is, the middle length) to be welded up definitely at all connections.

14. After welding of middle length of vessel is completed, rivet holes to be reamed and all rivet work at this ship's length to be carried out.

After finishing the middle length in the above fashion the erection of fore and aft sections will be carried out in the same manner. Figures 4 and 5 show details of construction.

For purposes of cost, strength and weight comparison, the figures for a welded job were compared with the cost of a riveted vessel of equal size. In these comparisons no consideration is given to the unseaworthy features of the riveted ships.

Between vessels of similar carrying capacity the welded ship is 4.48% shorter, 15 to 20% stronger, 19.15% lighter and the total cost is 2.80% less.

This 2.80% saving in cost is by no means the total saving, because to this may be added the saving in fuel required to drive the lighter ship.

Welding in the Construction of Naval Aircraft

By LIEUT. EDW. W. CLEXTON

†Address before the 33rd Annual Convention of the International Acetylene Association, November 17, 1932, by Lieut. Edw. W. Clexton, Shop Supt., Naval Aircraft Factory, League Island Navy Yard, Philadelphia.

THE application of welding to aircraft structures, in any serious extent, belongs almost entirely to the last twelve years. The first attempt to weld an airplane body structure of steel tubular construction was undertaken soon after the war and resulted in a fuselage in which the distortion was so great that the stern-post of the fuselage, which should have been vertical and in the axis of the airplane, lay one foot from the axis and inclined 15° to the vertical. Another attempt to weld a body structure of steel tubing, at approximately the same time, resulted in the fixture which was made up of 4-in. structural channels and angle iron of suitable proportions, being almost completely demolished due to the shrinkage of the welded structure. In contrast with these early attempts, it is now possible to build a welded tubular steel fuselage in which the stern-post is held to within plus or minus ten one-thousandth of an inch of its predetermined position, and jigs have been devised that permit the location of fittings with such accuracy that the holes for attachment of other structural parts can be drilled prior to assembly of the structure.

The process of welding has been the object of much distrust and the cause of many accidents due to faulty workmanship and improper design, but it has, nevertheless, survived and now stands second to none among the methods of joining airplane parts. It provides a simple union of the parts, makes possible the fabrication of extremely complex joints without great difficulty, is economical and quick and requires a low cost of working plant. The distrust, which is even now not entirely unfounded, results from the fact that the fusing of steel as a metallurgical process is not well understood by most mechanics and, as yet, no simple method has been discovered for determining the excellence of a weld without its impairment or destruction.

In the development of the technique of the application of welding to structures, it is impossible to attribute to any one factory, shop or organization, a major share of the credit, as the problem was attacked almost simultaneously by the entire aeronautical industry, and there has been a very free interchange of information within the group. The Naval Aircraft Factory has taken its part in this development, has freely drawn upon the experience of others and has just as freely made the results obtained at the factory available to all.

A paper such as this, naturally and necessarily, in view of the way in which the art has been developed, will be a review or recapitulation of knowledge already made available.

One of the first and most serious restrictions placed upon the use of welds in aircraft structures was the prohibition against placing any reliance upon welds in direct tension. This prevented plain butt welds of tubing and let to diagonal and serrated sections, with the result that the fish mouth weld is now regarded as standard. In building up fittings and in joining tubing to fittings, liberal use of gusset plates, much in excess of what would otherwise have been required, was demanded. These gusset plates must be so devised that the line of welding lies in or parallel to the line of action of the forces rather than parallel to it. This may be illustrated by a simple joint of a strut to a longitudinal (both tubular). The strut is normal to the longeron. To satisfy requirements the gusset may be a single plate let into slots in the two tubes, with welding along the slots, or it may be two right triangular sheets placed in the corners of the joint and welded parallel to the axis of the tubing.

Incidentally, this second method is cheaper in that the machine operations of slotting the tubes are not involved, but it requires a little more care in setting up the work for welding.

A third method of gusseting is to use a triangular plate

laid against the tubes. The base is welded parallel to the axis of the longeron. The plate is slotted from its apex about $^{2}/_{3}$ down to the base and a line of welding is run out this slot joining the gusset to the strut.

An incorrect method of gusseting is to wrap the plates around the tubes and weld circumferentially, as this procedure produces an abrupt change in the strength of the tube. This is particularly objectionable in engine mountings or other parts where severe vibrations are present.

These conclusions may seem ridiculously obvious, but I assure you that violation of these requirements is by no means a thing of the past and design must constantly be watched to guard against their creeping in.

Although butt welds are taboo for carrying loads in aircraft structures, the problem of making satisfactory butt welds cannot, on that account, be sidestepped, as it is necessary that tubular structures be completely sealed in order to exclude moisture. This is a measure of protection against deterioration that has been found to be absolutely essential for Naval aircraft in service conditions of exposure to salt water and salt air. As a result of this additional requirement imposed upon welded joints in tubular structures, some of these joints, particularly at the point of intersection of important fittings, are extremely complex, and the most highly skilled welders obtainable are required in order to obtain work that is free from distortion or cracking due to expansion and contraction of the metal in the process of welding. Such generally accepted practices as running lines of welds from points of intersection rather than toward them, of running lines of welds from the center of plate fittings in opposite directions toward the edges, rather than one continuous weld around the tube, and avoidance of joints between widely different thicknesses of platings and tubing, might very probably have been learned from the previous experience of others in welding, but the aircraft industry demonstrated its normality in learning these things for itself from experience.

A very common application of welding in aircraft is in the construction of fuel and oil tanks. Aluminum was adopted for these tanks on account of its lightness in weight, and welding was adopted, not primarily because of the superiority of welding as a process in joining metals, but for the simple reason it was the only reasonably satisfactory method of making joints in this material. The corrosive effect of the flux used in welding aluminum and its alloys forced a rigid method of cleaning in hot water, nitric acid solution and a final rinse in fresh running water. Shop practice in the manufacture of these tanks is now so standardized that it is difficult to recall that the problem involved considerable experimentation before a satisfactory solution could be found to the difficulty of the expansion and contraction of the metal in welding. This was solved practically in the shop by building many tanks, using slightly different types of beads in the vicinity of the welds and by varying widely the position of the beads. For many years these problems had been considered satisfactorily solved but, as will be pointed out later, it is possible that an entirely new and different solution must be sought.

The use of welding in aircraft is now being challenged seriously, not by the introduction of new processes of making joints in metal, but by the introduction of metals that lose most of their desirable qualities when subjected to heat sufficient to effect fusion. Aluminum alloyed with copper produces materials of construction that are comparable to mild steel in strength and are only one-third as heavy. This material has been welded in our shop, but very little can be claimed for the process, because the heat of welding seriously affects the shape of the parts, greatly increases its susceptibility to corrosion and reduces its strength by approximately one-half. Minor parts may be welded where the reduction in strength in the vicinity of the seam is not objectionable and the superior hardness and toughness of duralumin are desired in some part of the piece. The material in the vicinity of the weld is reduced in tensile strength and the metal in the seam is a casting. Heat treatment does not enhance the strength of the seam sufficiently to develop the strength of the wrought material. Substantial savings in weight for aircraft structure have been made by the substitution of this material for steel. The challenge of this material has been partly met by the use of alloy steel instead of mild steel, and partly by welding fittings for the attachment of floors, covers, cowling, accessories and equipment of all kinds directly to the steel structure, thus saving the weight of clamps and brackets that are necessary for making attachments to the aluminum alloy structure. This method of construction requires far greater foresight and planning on the part of the designer. All these various fittings must be incorporated in the structural members prior to welding into the structure, as the addition of these parts after the structure is complete and in correct alignment results in distortions that are not acceptable. The introduction of chrome molybdenum steel, with its air-hardening properties, its easy weldability and its superior cold-forming properties, was the greatest single factor in the swing toward fusion welding of steel in aircraft. The normalized material welded, such as is used in all steel tubular fuselage construction, is capable of 75,000 lb. per sq. in. tension and when heat treated for fittings will go as high as 200,000 lb. per sq. in. The use of chrome molybdenum steel tubing has become practically universal wherever alloy steel is used for a structural part of aircraft. At the present time no decided advantage can be attributed to either aluminum alloy or welded steel construction, as the balance is so close that one finds in airplanes of almost identical proportions, the two types of construction, the decision having been reached apparently on account of some personal preference of the designer rather than to any marked advantage of one over the other.

Aluminum alloys of the same type are being introduced into the design of fuel and oil tanks. Before adoption of the design of a fuel or oil tank, a sample tank must be subjected to a vibration test. The aluminum alloy tanks of riveted construction have been found to have far greater endurance under vibration than the welded aluminum tank. Sheets of aluminum alloyed with manganese are being used instead of ordinary commercial aluminum sheets. Variations in the location and attachment of interior reinforcing diaphragms are being tried, but it is possible that this problem will not be satisfactorily solved until there has been a sufficiently complete investigation to show the way to revising design and shop practice, to change the location of the welds and material affected by the welding operation to new positions where they will be less affected by the vibration.

Another serious challenge to the use of welding is the introduction of stainless steel. The heat of the welding operation greatly reduces the corrosion-resisting property of this material, and for the Navy, where exposure to salt corrosion conditions is a most serious problem, this quality is of paramount importance.

Materials, processes and the design of aircraft will be ever changing in the attempt to decrease weight and increase safety and strength. The welding process has played a major rôle in the development of aircraft up to the present time, and even greater and more difficult problems and conquests are in the offing for the future.

Welded Steel Pipe-Line of the Panther Valley Water Company

By FARLEY GANNETT

+Mr. Gannett is President of Gannett, Seelye & Fleming, Engineers, Inc.

THE largest welded steel pipe-line, so far as we know, to be centrifugally lined inside with a bitumastic enamel is being completed for the Panther Valley Water Company in the anthracite coal region in eastern Pennsylvania.

The purpose of this line, which is $30^1/_2$ in. inside diameter and about 10 miles long, is to carry approximately 10,000,000 gallons of water per day from an earth dam on Still Creek, which has recently been built, to supply several communities, collieries and other industries in that vicinity.

The route followed by this pipe-line includes most of the difficulties which any pipe-line may expect to encounter. Only a small part of it runs through what might be called easy going. The balance of it is either in rock cut or up and down over steep hillsides, through heavy timber, or side hill cuts along rivers or other streams, through culm banks and swamps, causing difficult construction and maintenance conditions. There are several crossings over streams where concrete piers carry the pipe, several crossings under concrete highways, through tunnels, an overhead crossing over a railroad and quite a long stretch where the pipe lies in the river bank between a concrete highway on the one side and the Little Schuylkill River on the other.

It was, therefore, not an easy thing to design a type of pipe-line which would meet the many tests which this sort of an alignment developed, and the selection of a steel line with two protective coatings inside and out, with most of the joints welded (about every third or fourth joint made of Dresser couplings), was finally selected as probably best overcoming all these difficulties.

Fig. 1—Pipe in Storage Yard Where Bitumastic Lining Is Applied

Fig. 2—Pipe Lined and Whitewashed Lying Alongside Prepared Trench

Fig. 3—Completed Pipe-Line at High Bridge Ready for Backfill

Four types of pipe were considered for this line: wood stave, cast iron, concrete and steel, and the final decision, namely, welded steel, $30^1/_2$ in. in diameter, lined with bitumastic enamel, was decided upon after comparing costs, as well as service.

This pipe is made of $^3/_8$-in. steel, which is about 50% thicker than required by the pressures to which it will be subjected. In order to preserve its carrying capacity up to ten million gallons per day, the bitumastic lining was adopted. The water which it carries is a normal soft water with about average tuberculation effect, so that in twenty years a considerable reduction in carrying capacity might be expected unless a preservative coating was applied on the inside. Welded joints were decided upon on account of the reduced friction due to the relative smoothness of the joint. Dresser couplings were used every 90 to 100 ft., and at all specials and valves, in order to give flexibility to the pipe to take up some of the temperature changes. The necessary air valves and blow-offs were installed, and about every mile a 30-in. control valve was put in the line as protection in case of trouble. These are all covered with concrete valve houses.

The pipe-line is practically all under ground with a minimum of one foot covering. In a few places, however, where it crosses gullies, railroad tracks and streams, it was necessary to carry it above ground on piers, in which cases it is carefully wrapped and protected against temperature changes.

The $^3/_8$-in. plates were made by the McClintic-Marshall Corporation, a subsidiary of the Bethlehem Steel Company, at its plant in Johnstown, and the pipe was fabricated at this Company's Leetsdale Pa., plant, the longitudinal welds being of the automatic electric type.

These welds were inspected at the Leetsdale plant by the Robert W. Hunt Company and tested to 375 lb. hydrostatic pressure, about five times the maximum static pressure when in service. The coupons of the longitudinal welds were also tested to see that the plate rather than the weld broke above the tensile strength requirement of 50,000 lb.

Before leaving the shop, the inside of the longitudinal welds were smoothed up to remove unnecessary roughness, and a priming coat was applied inside and out.

On arrival at Tamaqua, the nearest railroad point to the job, the priming coat was first touched up to cover all abrasions due to injury in transit or unloading, and then a second priming coat was applied by hand inside and out and a brush coat of bitumastic enamel about $^{3}/_{32}$ in. thick was applied by hand on the inside of the pipe along the longitudinal weld.

The Wailes Dove-Hermiston Company, who had the contract for painting and lining the pipe, set up a plant at Tamaqua, in the freight yards of the Lehigh & New England Railroad Company, where the final inside coating of bitumastic enamel, $^{3}/_{32}$ in. thick, was applied by a revolving process.

After the final priming coat had thoroughly dried, the 30-ft. lengths of pipe were placed on rolls and spun at a speed of about 200 r.p.m. While the pipe was spinning, the hot bitumastic enamel was applied from a long trough, which extended inside the pipe from one end of the pipe to the other, about which the pipe was spinning. When this trough was dumped suddenly, the enamel spread over the pipe in a uniform thickness with an exceedingly smooth surface. This was continued until the lining had cooled, the cooling process being aided by a spray of cold water on the outside of the pipe and by an air blast on the inside. After the inside lining had thus been applied, a heavy whitewash coat was put on the outside of the pipe in hot weather to keep down the temperature of the metal where exposed to the hot sun.

The pipe was then loaded on trucks by a crane and hauled to the pipe-line location. Three and sometimes four lengths of pipe were electrically butt welded on the job, using a $^{3}/_{8}$-in. bare-wire welding rod and always welding from the top, the pipe being rolled to make this possible. These lengths of 90 to 100 ft. were then lowered into the trench where the Dresser coupling joints were made.

Following this operation, any scratches or abrasions to the outside priming coat were repaired with a hand brushed coat of primer and the inside and outside of the welded joints and Dresser coupling joints were covered with a hand brushed coat of bitumastic enamel and the outside of the joints with two coats of paint.

The pipe was inspected on arrival in the yard, on completion of the inside enamel coat, on its arrival in the field and after it had been finally placed in the trench and the Dresser coupling joints completed and the enamel applied to these and the welded joints. Manholes were welded into the pipe about every 1000 ft. in order to make possible this final inside inspection.

The pipe was then back filled, with the exception of the Dresser coupling joints, and at every gate valve about a mile apart, tests were made to determine leakage, if any, under 100 lb. water pressure. After these tests had been made and were tight, the Dresser coupling joints were back filled. Practically no leakage exists in the line.

At points where the pipe-line changes direction suddenly, either horizontally or vertically, heavy concrete anchors were constructed to prevent movement of the pipe at such points. The greatest hydrostatic pressure to which the pipe will be subjected in service is about 70 lb.

Where the pipe passes through soil which is acid, and there are quite a number of such places, due to the culm from the coal mines and acid water from these mines, the pipe was given an outside coating of bitumastic enamel, hand applied, and then the entire trench was back filled with clay to keep the acid soil or water from contact with unprotected steel.

This work, which involved an earth filled dam and this 10-mi. pipe-line, was designed by Gannett, Seelye & Fleming, Engineers, Inc., of New York and Harrisburg, which firm also had the general contract for construction. The job was started in April 1932 and was practically completed by the end of December 1932.

ANNUAL MEETING

American Welding Society

33 West 39th St., New York
April 27 and 28, 1933

PROGRAM INCLUDES

Business Meetings, Discussion of Section Activities, Presentation of Important Committee Reports, Codes and Specifications and Research Papers. A Lecture on Structural Steel Welding.

Welding of Pressure Vessels

†This article contains some recent additions to the A. S. M. E. Boiler Construction Code with special reference to welded attachments of nozzles and outlet connections, with a Foreword by Mr. C. W. Obert, Chairman, Welding Conference Committee, American Welding Society.

Foreword

THESE revisions of 1932, which are now on the press and will soon be issued, embrace extensive changes in portions of the Code in which the rules have been either incomplete or perhaps indefinite in their application. There have been, as you probably know, certain portions of the rules in the Code which the Boiler Code Committee has admitted to be incomplete, because of lack of available data on the subject. Among these may be noted such items as the proper methods of attachment of nozzles, the reinforcement of openings cut in shells or heads, the weakening effect of a number of holes cut in a cylindrical shell, etc. Efforts have been made by the Boiler Code Committee over a period of years to obtain satisfactory data to permit the formulation of suitable suggestive or mandatory rules for these constructional details.

In the 1932 revisions will appear new mandatory rules in both the Power Boiler and Unfired Pressure Vessels Sections of the Code, which will give adequate rules for all methods of attachment of nozzles and outlet connections to cylindrical shells and dished heads. Accompanying these rules are charts and formulas covering the design of reinforcements when needed and fairly complete provisions for attachment, whether riveted, welded, bolted or expanded. The feature of these new rules is the method provided for determination of maximum diameter of unreinforced opening, by charts based on critical factors involving the shell diameter, the thickness of the shell and the stress efficiency of the plate.

In addition to the above there are many revisions

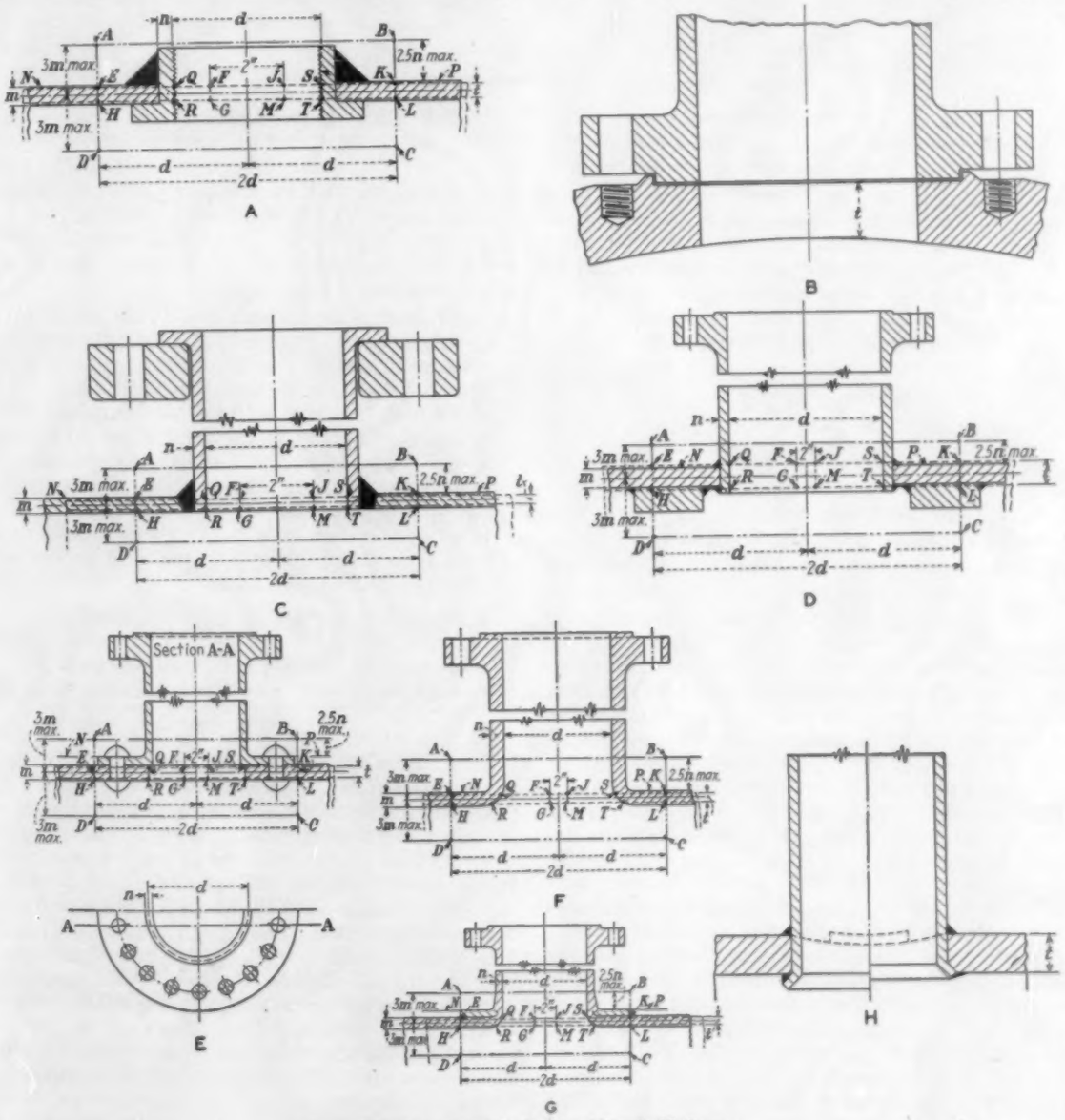


Fig. U-3 (Revised)—Types of Nozzle Fittings

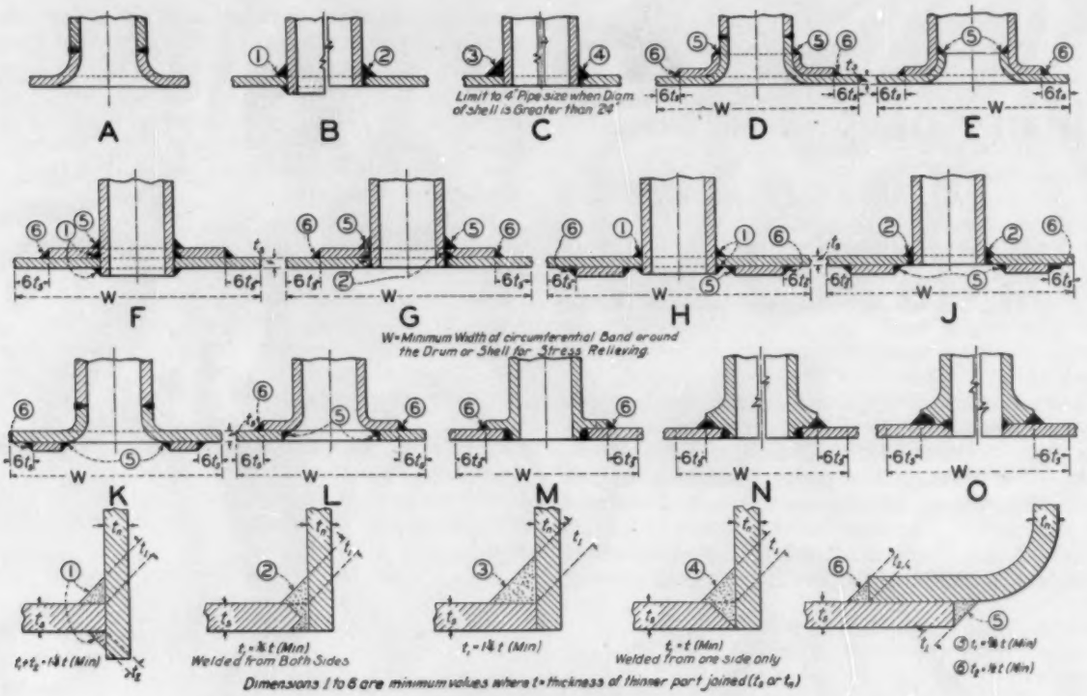


Fig. U-16—Some Acceptable Types of Fusion Welded Nozzle Construction

Note: The above illustrations are diagrammatic only. Any other design that meets the requirements of Par. U-59*b* will be acceptable.

which either amplify or clarify the new welding rules which were adopted and incorporated in the Code last year. Everyone interested in these new welding rules should be informed of the new revisions and urged to obtain copies thereof for their education.

C. W. Obert,
Chairman, Welding Conference, A. W. S.

[EDITOR'S NOTE: There follow portions of Paragraph U-59 entitled, "Nozzle Openings," of the A. S. M. E. Boiler Construction Code for Unfired Pressure Vessels which relate to welding. Similar rules exist for the power boiler section.]

Abstracts from Par. U-59 Revised. Nozzle Openings

Reinforced Openings.—(*b*) An opening in the shell of a pressure vessel with a diameter greater than the maximum unreinforced opening permitted by section (*a*) shall be provided with reinforcement. Openings of the reinforced type shall consist of one or more reinforcing rings or flanges riveted, welded or brazed to the shell and/or a tube or pipe extension or fitting welded to the shell and/or welded to or integral with the reinforcing flange.

The thickness of a tube or pipe extension welded to the shell and/or a reinforcing ring or flange shall not be less than that for standard weight pipe of the same diameter and shall comply with Par. P-23 of Section I of the Code.

All circular or elliptical openings of the reinforced type shall comply with the following requirements:

1. On a line parallel to the longitudinal axis of the shell and passing approximately through the center of the opening and through the weakest section of a riveted reinforcing ring or flange (sectional views in Fig. U-3), the total cross section in the complete reinforced opening, including the shell and cross section of fusion welds if any, and deducting for rivet holes if any, within the limits defined below (defined by rectangle *ABCD* in the sectional views) shall be at least equal to the cross section (*EFGH* plus *JKLM*) obtained by multiplying the shell thickness t required by Par. U-20, using $E = 0.90$, by twice the diameter d of the opening, less 2 in. The above-mentioned limits are:

(*a*) A distance on each side of the center line of the opening equal to the actual inside diameter d of the opening in the shell in the finished construction (lines *AD* and *BC* in the sectional views).

(*b*) A distance on each side of the middle line of the actual thickness m of the shell equal to 3 times such actual thickness, except that in no case shall the limits extend along the tubular portion of a connection beyond the surface *NP* of the shell, or of the reinforcement if any, more than $2^1/_2$ times the thickness n of the tubular portion (lines *AB* and *DC* in the sectional views).

When there are two or more adjacent openings, the limits (defined by *AD* and *BC*) for the openings shall not be considered to overlap, and in no case shall any portion of a cross section be considered to apply to more than one opening.

2. On either side of the line parallel to the longitudinal axis of the shell, as determined in (1), the strength of the attachment to the pressure vessel of each separate part entering into the fabrication of a reinforced opening shall be at least equal either to the tensile strength of the cross section of the reinforcing part within the above limits (within the rectangle *ABCD*), or to the tensile strength of a cross-sectional area (*QFGR* plus *JSTM*) determined by multiplying the shell thickness t required by Par. U-20, using $E = 0.90$, by the diameter d, less 2 in. of the opening in the shell in the finished construction, whichever tensile strength is the smaller. For riveted construction the strength of attachment is the shearing strength of the rivets, and for fusion welded construction it is the strength of the weld in shear or in tension, whichever is smaller.

The unit working shear stress of a weld shall not ex-

ceed 0.8 times the allowable working stress in tension for the class of fusion-welded vessel for which the welding process is suitable.

For fusion-welded connections, in addition to complying with the rules given above in (2), the following additional requirements shall be met.

Where the thickness t of the thinner of the two parts being joined is $^3/_4$ in. or less, the dimensions of the welds shall not be less than the requirements given by the formulas in Fig. U-16.

Where the thickness t is greater than $^3/_4$ in., the dimensions of the welds shall not be less than the requirements given in Fig. U-16, using a value of $^3/_4$ in. for t in the formulas.

Fusion-Welded Connections.—Materials for fusion-welded connections shall be in accordance with Par. U-71*b*.

All welding for fusion-welded connections shall be equivalent to that required for the particular class of vessel to which the connection is attached. X-ray examination may be omitted.

The fusion welding of dome flanges shall also comply with additional rules given in Par. U-33.

On Class 1 vessels all connections after being attached by fusion welding shall be stress-relieved.

On Class 2 vessels requiring stress-relief, all connections after being attached by fusion welding shall also be stress-relieved.

On Class 2 vessels which do not require stress-relief; all connections after being attached by fusion welding shall be stressed-relieved except the following:

(*a*) Connections formed by welding a plain end pipe, welding neck or nipple directly to the vessel without the attachment of additional material, the diameter of the opening of which does not exceed 10 per cent of the outside diameter of the shell (some such connections are illustrated in Fig. U-16 *A*, *B* and *C*).

(*b*) Connections formed by welding to such vessels an hydraulic coupling or special forging for a threaded opening not to exceed 3-in. pipe size.

On Class 3 vessels connections after being attached by fusion welding need not be stress-relieved.

All connections attached by fusion welding to forge-welded, riveted, brazed or seamless vessels shall be stress-relieved in accordance with the requirements for connections on Class 2 vessels. If any such vessels are to be used for service equivalent to Class 1 fusion welding, then any fusion-welded connection must be stress-relieved.

Fusion-welded connections which require stress-relieving and which are attached to vessels whose seams are of riveted construction shall be fabricated and stress-relieved prior to the making up or attachment of the courses by riveting. If they do not require stress-relieving and are attached after riveting, the welds shall be located at a distance from the riveted seam at least equal to the diameter of the opening plus 4 times the plate thickness of the shell.

Fig. U-16 illustrates some types of fusion-welded connections which are acceptable.

Discussion of Paper by H. H. Tracy Entitled, "Welded Joints for Seismic Stresses in a Tall Building"

By S. C. WEISKOPF *and* JOHN W. PICKWORTH

✦Paper published in November 1932 issue of Journal of the American Welding Society. Messrs. Weiskopf and Pickworth are Consulting Engineers.

A NUMBER of points in the article, "Welded Joints for Seismic Stresses in a Tall Building," by Mr. H. H. Tracy, in your issue of November 1932, interested us.

First, Mr. Tracy states in the first paragraph of the article: "Although several buildings in Japan had been designed to resist seismic stresses, they were not more than six stories in height and, therefore, not comparable to the thirteen-story Edison building." In the Mitsui Main Building, Tokyo, Japan, a five-story building designed by us, and probably one that the author had in mind (see article, "Tokyo Bank Building Designed to Resist Earthquakes," published in the June 23, 1927 issue of the *Engineering News-Record*), occurred some very large bending moments in columns and girders, due to a 42-ft. 6-in. story height between the first and second floors. The moment between the member (a double truss) connecting to one side of a column at the first floor, was 938,000 ft.-lb. for an interior and 1,876,000 ft.-lb. for an exterior column, compared to a moment "in excess of 600,000 ft.-lb." mentioned by Mr. Tracy. According to the Japanese law, it was necessary to use a fiber stress of 16,000 lb. per sq. in. in resisting these moments.

Second, the article speaks of a column, consisting of a 16-in. x 363-lb. H-section with one 18-x $1^1/_8$-in. cover plate on each flange, taking a large direct seismic stress. Presumably such a column would also be subject to a considerable bending moment. We are curious as to how the pull from the beam flange was transmitted through the cover plate into the column if the detail shown in Fig. 3 was used in such a case.

Third, Mr. Tracy speaks of the compactness of the welded connections and the space saved over what might have been used in a riveted design. It should be borne in mind that to resist earthquake shock a steel frame should not only be strong enough to withstand being demolished; it must also avoid such excessive deflection as might crack and shake loose the masonry walls and floors. From this view-point the problem is analogous to that of wind on high buildings. In the past some rather high structures have been built which, while probably quite safe against being blown over by a high wind, sway so as to cause cracks and an unpleasant sensation. The fault has been in squeezing the structural requirements too far. Granting that the same strength can be obtained in a connection in less space and that shallower members can be employed in a welded design than in a riveted one, care should be taken, regardless of the type of connections, to obtain a structure of sufficient rigidity.

Welding Aids Food Purity

By **O. C. JONES**

†Mr. Jones is connected with the Technical Publicity Department of The Linde Air Products Co.

IN THE food industries there are two vital considerations that directly concern the use of all of the containers in which the products are handled. These are cleanliness and resistance to corrosion. In order to obtain absolute cleanliness it must be possible to completely sterilize the containers and in order to obtain long life they must be constructed of a material which resists corrosion. Stainless steel has been found particularly applicable for such work because of its great resistance to the various organic acids that are found in certain food products. The same general type of steels, namely, the 18 per cent chromium and 8 per cent nickel which have been used so effectively in other industries to resist corrosion, are now being used in the food industries.

A large chocolate manufacturing concern in the East was recently desirous of converting its vats and tanks into stainless steel equipment in order to more effectively combat corrosion. The question of fabrication of this equipment was brought up. The oxyacetylene process was chosen as the ideal method of fabrication since by welding the seams in the containers, all crevices, cracks or other tiny openings prone to occur in other types of joints, would be effectively eliminated, thus removing beyond any possibility the presence of bacteria in such places.

The accompanying illustration shows one such tank completely welded. When the work was first started some trouble was found due to warping at the seams as the heat of the blowpipe was applied. An oxyacetylene service operator was called in for advice regarding this and he suggested flanging or breaking each seam or edge about $^{3}/_{16}$ in. Each edge was thus at right angles to the main part of the sheet for the full length of each section. The flanged edges were then placed together and welding started at one end, melting down the flanges to form the weld without the use of welding rod. The molten metal from the flanged edges is sufficient in light sheet metal to give any excess weld metal necessary. This procedure completely eliminated any trouble in warping and also gave a joint that was perfectly flush on the inside of the seam.

Certain precautions are necessary in welding this type of steel which should be thoroughly understood before any effort is made in this direction. Such steels containing nickel are not subject to the brittleness encountered in other types of rustless irons or steel when they are exposed to the heat of the welding blowpipe. They do not air harden and retain their ductility without any heat treatment. The weld metal itself, which should be of the same material as the base metal, when cooled either rapidly or slowly, is malleable and ductile and therefore requires no heat treatment.

Although it is possible in some cases to weld this type of metal without flux, much better success is attained by the use of a flux which will amply take care of the infusible oxides which form as a slag on the surface of the molten metal. These oxides consist chiefly of chromium oxide together with smaller amounts of iron oxide, manganese oxide and silicon. For this purpose the flux must be sufficiently fireproof to adequately protect the molten metal and hot metal adjacent to the weld from oxidation, and it must also be correctly compounded to dissolve the refractory chromium oxide with ease. Such a flux specially designed for welding high chromium steels is now in the market and is known as "Cromaloy Flux." It has a high solvent power for chromium oxide and is highly resistant to heat. Best results are obtained through its use.

Welds in 18-gage sheet will have a yield point of 55,000 lb. per sq. in. and an ultimate strength up to 65,000 lb. per sq. in. Blowpipe annealing or simple annealing does not improve the quality of the welds in this material and is not recommended. From a welding standpoint, this composition, namely 18 per cent chromium and 8 per cent nickel, forms a most satisfactory alloy and will be found highly satisfactory for making welded products which must resist corrosion.

It is easily understood then why the chocolate manufacturer chose both the 18–8 stainless steel and oxyacetylene welding in order to make his corrosion-proof and sanitary vats. Other manufacturers of food products when considering the use of new equipment or replacing old equipment should carefully investigate the superior products made possible through the use of the oxyacetylene welding process. They will find fabrication by the use of the blowpipe both efficient and rapid and will profit by its use.

This 18 Per Cent Chromium, 8 Per Cent Nickel Stainless Steel Vat Was Completely Fabricated by Welding

Chrome Nickel Steel Riser Cutting

By **R. B. AITCHISON**

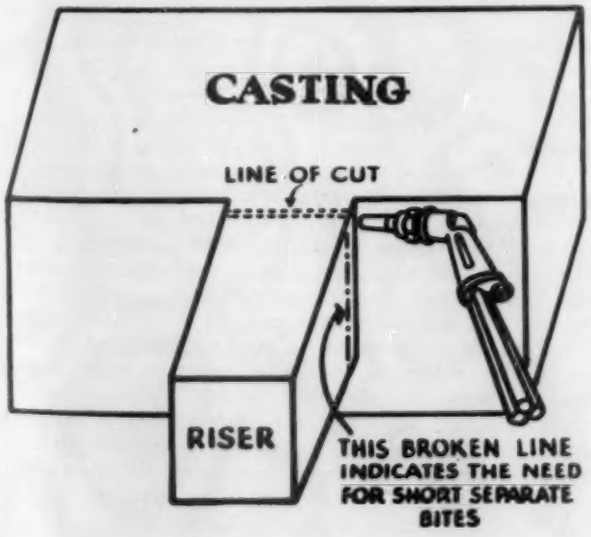
✦Paper read before the 33rd Annual Meeting International Acetylene Association, Philadelphia, Pa., November 16, 17, 18, 1932, by R. B. Aitchison, Oxweld Acetylene Company.

DURING the last few years there has been a remarkable growth in the development and use of the chrome nickel steels. Steel foundries, particularly those using electric furnaces, are giving more and more attention to the manufacture of chrome nickel steel castings.

In the steel foundry industry it has for many years been standard practice to remove risers by means of oxyacetylene cutting. When the foundries first began to produce chrome nickel steel castings, it was found that the customary oxyacetylene cutting procedure would not work with these oxidation-resistant steels. For a time, then, it was necessary to try other expedients. Nicking and flogging could be used for the smaller risers, but for chrome nickel risers over $2^1/_2$ in. in diameter, flogging is fraught with a certain amount of danger, in that there is an equal chance of the break taking out part of the casting proper. Grinding, too, has certain disadvantages: the wheels are quite expensive, last but a short time and are at best only of advantage where the casting, wheel and riser can all be handled easily and efficiently. Obviously a very heavy casting, or one where the risers are hard to get at, would present handling problems that might often be extremely difficult.

Another method tried during this period of development was the use of an oxyacetylene welding blowpipe with a large head or tip, the procedure consisting in simply melting out a kerf and blowing the slag free.

As none of these methods were comparable in speed and economy with the oxyacetylene cutting of plain steel risers, representatives of the oxyacetylene industry undertook a thorough investigation of the possibility of developing a cutting procedure which would be suitable for chrome nickel risers.



On first thought, it may seem a trifle incongruous to speak of using oxygen for the removal of oxygen-resistant steel, and perhaps this was the reason why the cutting of chrome nickel steel risers fell at first into the category of "it can't be done."

It will be remembered, however, that at one time cast-iron cutting also fell into the class of "it can't be done," and years ago some very elaborate explanations were made to prove how impossible such work was of accomplishment. In spite of, or perhaps because of, such prophecies, the oxyacetylene industry went ahead and the letter "t" was removed from "can't" and today, "it can be done." So it is today with chrome nickel steel risers, particularly that variety known as the "18 and 8." I do not wish to infer that all chrome alloys can be cut, neither does such cutting refer to the severing of plate.

The first work done by the oxyacetylene cutting process used a steel feeder rod to aid the oxidation process. By this is meant that a steel or iron rod was fed into the kerf while the cut was being made. Obviously this could only be applied to small risers because it necessitates using the blowpipe with one hand while the rod is fed in by the other. The cuts were slow and thus expensive.

The steel foundries demanded something better than any of these methods and their demand was met by the development of a satisfactory oxyacetylene cutting technique. As a result, the cutting of chrome nickel risers has been done on a commercial basis over the past three years. Before describing the procedure, it will be of interest to review the problem for a moment. We are dealing with an alloy very much more resistant than plain steel to oxidation by ordinary atmospheric conditions or that hastened by high temperature. The alloy obtains this characteristic from the chromium and nickel, both of which, generally speaking, are impervious to oxygen attack. The first point to remember then is that the chromium and the nickel will defeat the oxygen jet under ordinary circumstances and with the usual cutting manipulation. To go back to cast-iron cutting again for a moment, most of you are undoubtedly familiar with the blowpipe operation which through weaving from side to side enables the iron oxide to wash out particles of graphitic carbon, which, if the normal blowpipe manipulation were used, could be counted upon to defeat the cutting process. So, too, in the cutting of 18 and 8 risers, the chromium and nickel particles will stop the oxidation if the ordinary blowpipe manipulation is used To swing from side to side would mean a very wide kerf, consume too much metal and, thus, too much oxygen, for this is a production operation, not a scrapping process, and, therefore, cost must be considered of primary importance.

The casting is presumed to be on the cleaning floor and the blowpipe must now be made ready. As we are going to need a lot of heat, it is recommended that one size larger nozzle or tip be used than would be the case were the casting of plain steel. The oxygen hose should preferably be $^3/_8$-in. diameter in order to secure ample volume. Tip or nozzle should preferably have six preheating jets rather than the usual four or less. The oxygen cutting pressure needs to be increased perhaps 15 to 20 per cent more than would be the case were the casting of ordinary steel.

In connection with this cutting, I am speaking of experience with an injector type blowpipe in which the oxygen aspirates sufficient acetylene to maintain a neu-

tral preheating flame. The blowpipe is now adjusted so that the preheating flame will never be oxidizing when the cutting jet is wide open. A mere feather of acetylene in the preheating flame is not objectionable, in fact, may be of help to the beginner, but a distinct and heavily carbonizing flame is detrimental to the cutting action in that the preheating temperature is lowered.

From the illustration it will be evident that the cut is started horizontally across the top surface of the riser and that it progresses downward in a vertical plane from the upper surface to the lower. During the cutting the blowpipe is moved up and down.

In starting to cut operator first proceeds to preheat the top of the riser across what is going to be his line of cut. It is necessary to do this in order to establish a straight and easy kerf. If this isn't done, then there is quite some likelihood of the kerf going wild and a pocket forming with the result that through cutting will stop. When the line of cut has been preheated to a dull red, the operator starts to concentrate his preheat at the point where he will start cutting. Very quickly the spot will become white and start to melt. The blowpipe tip is directed in a horizontal plane across the top. He will now move the blowpipe so that the inner cone of the preheat will be perhaps $^3/_{16}$ in. away from the face of the riser and as he does so turns on the cutting oxygen. If the preheating has been sufficient, the cut will start and the operator will be able to look right into the whole of the kerf and watch his progress. The slag will be much more incandescent than is the case with plain steel, will crackle and spark violently. The operator will, with gentle but speedy up and down motions, start to bite through the riser. The noise will resemble that occasioned by the rapid sawing of hard wood. He must keep these motions up and down and not swing from side to side, otherwise he will consume too much time and material. He will notice that the cut is not always sustained at the point directly in front of the blowpipe tip. This is probably due to the fact that the cutting oxygen is still cool even after passing through the preheating flame, and this accounts for the suggestion made to keep the inner cone a short distance from the face of the riser. The operator should not stop his work because of this refractory spot as he will notice that this point will become oxidized and carry off as he goes along, he unconsciously varying the distance between the blowpipe tip and the face of the casting to achieve this result. If the operator stops during a cut and it cools off below red, it will be found somewhat difficult to pick up the cutting smartly, due undoubtedly to the fact that there is now a surface layer of slag added to the kerf.

In starting an operator out on this work it is advisable, in order to overcome the psychological factor of "it can't be done," to use a larger nozzle or tip and more oxygen and acetylene than is really necessary. The immediate thing to bear in mind is that it can be done and once the new operator is over this hurdle, the cutting down of pressures and use of correct tip size can and must go forward, because cutting chrome nickel steels is more expensive than cutting plain carbon steel, but how much more will depend very largely on how much attention and aid we of the oxyacetylene industry give to our steel foundry customers.

A skilled operator will sever a 6 x 6 in. chrome nickel steel riser in 3 to $3^1/_2$ min. cutting time which indicates that there is not a great deal of difference in time between ordinary steel riser cutting and the cutting of the chrome nickel risers once a man has learned the practice. The kerf made in this cutting is about one-third wider than that of carbon steel of same diameter. But the cut surface will, of course, not be as smooth as in plain carbon steel work, because of the need for hand movement in cutting chrome nickel risers.

The cut can come within reasonable distance of the casting proper. Again though, judgment must be used in the beginning, for it is far better on the first dozen castings cut to leave a $^1/_2$-in. stub for finish grind than to take off the riser to within $^1/_4$ or $^3/_{16}$ in. and take a chance of spoiling the casting through cutting in. Experience will here again show the individual how near he can go.

The cutting of chrome nickel risers should be done prior to any heat treatment given the casting.

Very small risers, 1 to $1^1/_2$ in., can be nicked from each side to a depth of about 25 per cent of the total thickness and flogged while hot. If this flogging is done directly after nicking, there will be much less danger of damage to the casting and the nick on either side tends to make certain that the break will be clean.

The suggestions made here should not be taken as inferring that this is the only method and manipulation for this work. They are given because the author knows from experience that this method does work. Modifications will come to the individual with practice and experience.

Some Economic Aspects of Welding Aluminum

By **D. E. ROBERTS**

†Paper read before the 33rd Annual Meeting, International Acetylene Association, Philadelphia, Pa., November 16, 17, 18, 1932 by D. E. Roberts of The Linde Air Products Company.

BUSINESS conditions over the past few years have acutely focused the attention of production managers on every phase of the cost of industrial processes. The necessity for lowering production costs has been imperative, and oftentimes vital to economic survival. It is, therefore, timely to discuss an application of welding which is broadly practiced, and bids fair to enjoy continuous and material growth because of the many desirable inherent features of the metal.

The record of the invasion of aluminum into industry is most impressive when it is realized that this youthful member of the metallic family made its bow commercially on February 23, 1886, when Charles Martin Hall, a young man of twenty-two, only eight months out of Oberlin College, discovered an economical method of producing this silvery, white metal in his wood-shed laboratory. It is pleasant to recall that, unlike most inventors, Mr. Hall reaped a handsome profit from his invention and actively participated in the inception and organization of the aluminum industry.

Most of us became acquainted with aluminum in our kitchens, but today it may be found in almost every branch of industry, including the electrical, automotive, aircraft, and more recently this metal and its alloys are in demand in the structural, architectural and decorative fields for the production of window sash, doors, building fronts, skylights, gutters and leaders, building domes, etc. In transportation it is gaining an important foothold in the fabrication of street railway cars and power transmitting elements, such as engine connecting rods, etc., and is destined to contribute some very substantial savings to transportation costs.

Perhaps the most valuable property of aluminum is its combined lightness and strength, with ample ductility. It has excellent resistance to corrosion and therefore finds extensive use in the chemical and allied industries. Not the least of its valuable characteristics is its easy weldability, which is an essential element today in the extensive application of any metal or alloy in industry. Because aluminum, and in speaking of the metal I refer also to its common alloys, is so richly endowed with properties that commend it for industrial use in a great many fields, we envisage a much larger use of welded aluminum products than this market has heretofore enjoyed. We are of the opinion that a more general use of welded aluminum products awaits unanimity of thought with respect to the method of blowpipe welding among the producers of aluminum and those industries which are chiefly interested in its welded fabrication.

Two methods are in common use. The oxyacetylene process is conceded to be the only practical blowpipe method for welding aluminum in thicknesses above $^1/_8$ in. It has long been contended, however, that the oxyhydrogen process should be employed on gages lighter than $^1/_8$ in. If we turn back the pages of history to the early days of fabricating aluminum with the blowpipe we shall perhaps find some logical reason why oxyhydrogen gained popularity in the welding of the lighter gages. At that time commercial oxygen was largely produced by the electrolytic process, so that the sources of hydrogen supply were relatively numerous and fairly well distributed. Today practically all commercial oxygen is produced by the liquefaction process, which has materially limited the availability of hydrogen except in the large industrial centers. Acetylene and carbide distributing stations are conveniently located everywhere. The small fabricator outside of the large cities who continues the use of hydrogen is therefore required to charge into his production costs an appreciable item for freight, to say nothing of the inconvenience of securing a commodity in a distant market.

Although certain metallurgical advantages were claimed for hydrogen in aluminum welding, it is probable that its popularity rested principally upon its lower flame temperature, which made possible the welding of the metal by less skilled operators. The agencies for instructing operators in welding aluminum were not at that time as well developed as at present and this was an important factor from the standpoint of getting men quickly into production work. It is also to be noted that there were not available at that time the excellent fluxes and rods for aluminum welding which are found on the market today, so that it was natural for fabricators of aluminum to follow the course of least resistance without too close scrutiny of production costs. In spite of the use of the best practices then known some weld failures resulted so that it seemed illogical to impose a greater burden upon the skill of the operator incident to the use of acetylene. This refers particularly to welding the alloys, which the advent of the silicon alloy aluminum rod has greatly simplified, by eliminating the delicate preheating and cooling operations which were essential for successful results. So you will observe that in the last decade the methods and materials for welding aluminum have progressed to such a point that satisfactory fabrication of even quite intricate designs presents no problem.

It is not the purpose of this paper to dwell upon the technique of aluminum welding, but rather to direct your attention to the cost of welding by the two blowpipe methods heretofore mentioned. An intelligent discussion of this matter should comprehend a knowledge of the characteristics of the two flames. The use of hydrogen in combination with oxygen unquestionably antedates the oxyacetylene process, but because of its relatively low flame temperature has been practically superseded by oxyacetylene for all welding applications with the possible exception of lead burning. The oxyhydrogen flame is produced by a combination of two volumes of hydrogen with one volume of oxygen, forming water vapor. It was early found in blowpipe welding with oxyhydrogen that the water vapor which is produced exclusively and abundantly provokes considerable oxidation of the molten metal at the welding temperature and that all efficient joining was impossible. The only artifice which would mitigate the deleterious effect of the neutral hydrogen flame was to dilute the water vapor with an excess of hydrogen if good welds were to be anticipated, so that the theoretical proportions of gases were raised from two to three, or even four, volumes of hydrogen for one volume of oxygen. In spite of this artifice of using excess hydrogen the undesirable oxidation is not entirely eliminated. The necessity for using an excess of hydrogen in the oxyhydrogen flame has been amply borne out in observation of relative volumes of oxygen and hydrogen during production operations. It may also be easily verified by allowing a properly adjusted oxyhydrogen blowpipe to burn over a period of an hour and measuring the relative gas volumes. This is an interesting test as compared to the equivalent oxyacetylene flame for the same speed of welding.

Contrast with this the oxyacetylene flame. Theoretically, it requires $2^1/_2$ volumes of oxygen to completely burn 1 volume of acetylene. Practically, it is necessary only to furnish approximately one volume through the blowpipe, the additional required oxygen being supplied from the atmosphere surrounding the burning envelope. The initial stage of the combustion of acetylene with an equal volume of blowpipe oxygen produces hydrogen and carbon monoxide as intermediate products. These serve the important function of a protective gaseous atmosphere about the weld, strongly reducing in character, which eliminates the formation of oxides detrimental to good weld quality.

Considering the fundamental characteristics of the two flames, it is obvious that the oxyacetylene flame has certain innate properties which make it infinitely more desirable in fusion welding than the oxyhydrogen flame, which in its neutral condition is unsuited to such operations. Because of the low visibility of the hydrogen flame it is quite difficult to adjust it always to the same condition; the neutral oxyacetylene flame is easily and quickly attained without a trial melting of the metal. As is well known, the hydrogen flame is a long, bushy, diffuse flame as compared to the short, concentrated flame of the oxyacetylene blowpipe, and it is apparent that in the application of these flames the hydrogen flame necessarily heats up a larger area and does not permit of the efficient heat utilization possible with the oxyacetylene blowpipe. This immediately becomes a consideration in welding aluminum, as the coefficient of expansion of this metal is almost twice that of steel, and in order to minimize distortion it is desirable to accomplish the welding as fast as possible with a source of highly localized heat. The temperature of the oxyhydrogen flame is nearly 2000° F. lower than the oxyacetylene flame. I do not mean to imply in drawing your attention to the elemental properties of these two flames that good welds cannot be made in light gage aluminum with oxyhydrogen, for such is not the case although the heat of the oxyhydrogen flame is entirely

inadequate in the welding of the heavier gages for which oxyacetylene is universally employed.

Because of the lower flame temperature of oxyhydrogen, less skill is demanded of the welder, although new operators are just as easily trained to use acetylene as hydrogen. It has been sometimes contended, though not in recent years, that there was a deposition of carbon during welding with oxyacetylene which was not present in using hydrogen. We have observed oxyhydrogen welding where the same reaction obtained, and we are inclined to believe that whatever the cause it has no bearing on the physical properties of the resultant weld, nor does it contribute to additional cost in the finishing operation.

Preference for hydrogen is often predicated on the theory of better physical properties in the weld. This claim is unsupported, not only by the service of oxyacetylene fabricated aluminum products over a long period, but it has been definitely proved through careful research that no significant difference exists between the physical properties of welds produced by the two methods. Equal welding speed, if not greater, is possible with the higher flame temperature of oxyacetylene. With the efficient fluxes, rods and improved technique which have been developed, there is little reason from the standpoint of equality of physical results to continue the use of oxyhydrogen welding, particularly when the cost is decidedly in favor of acetylene.

This fact recently became apparent to a large manufacturer of aluminum furniture, and the general manager and metallurgist cooperated in a series of production tests to determine the actual facts as to relative merit of welding aluminum by oxyacetylene and oxyhydrogen. For this purpose one hundred aluminum chairs were welded; fifty by oxyacetylene and fifty by oxyhydrogen. The plant operators had used oxyhydrogen for many years and were inexperienced with oxyacetylene. The results they achieved were therefore the more remarkable. Five operators participated in the tests, each being a specialist on some phase of the welding operation. The normal time for welding fifty chairs was nineteen hours. The welding time with oxyhydrogen was 21.1 hr. and with oxyacetylene 24.9 hr. The difference in time was rightly attributed by the management to the inexperience of the operators, all tests heretofore having shown equal or better speed with the hotter oxyacetylene flame. The finishing time was identical, as was the chair strength determined by accelerated fatigue tests for chair life. There was no difference in the appearance of the welds.

Of more significance are the relative consumptions of gases. Let me remind you that we are comparing equal amounts of useful work in the shape of aluminum welded production. The fifty oxyhydrogen welded chairs required 485 cu. ft. of hydrogen and 212 cu. ft. of oxygen, a ratio of about 2.3 to 1, which indicates very efficient use of this flame. The fifty oxyacetylene welded chairs consumed 169 cu. ft. of oxygen and 159.5 cu. ft. of acetylene. Approximately 25 per cent more oxygen was required in doing the same amount of aluminum welding with hydrogen as a fuel as compared to acetylene.

On the basis of prices paid for gases by this manufacturer, the oxyacetylene method using dissolved acetylene, shows a 30 per cent saving in welding costs, which is increased to approximately 47 per cent if generated acetylene is substituted, a logical installation for such large-scale production welding. A check of many other fabricated aluminum jobs tells the same story with resultant savings for oxyacetylene, and usually in larger degree, as the tests referred to represented the use of oxyhydrogen under the best possible conditions by most experienced operators.

The acetylene industry is desirous of expanding its market for acetylene and carbide and the producers of aluminum wish to see a much larger use of fabricated aluminum. Our common interests can be most quickly attained by a unanimous recommendation for the oxyacetylene welding of aluminum and its alloys in all gages. It has been proved and amply demonstrated, that, metallurgically, welds produced by oxyacetylene are equal to those produced by oxyhydrogen in every respect and, what is much more important, at lower cost.

We are coming into an age which will be remembered for the diversity of its use of alloys, and the fabricating methods applicable to every metal and alloy must be placed upon the soundest economic basis. It is time that we should dissipate any vestige of doubt among aluminum fabricators as to the supremacy of the oxyacetylene flame in the welding of aluminum. The acetylene and apparatus industries are well qualified and are the logical agents to teach proper aluminum welding technique. Such expense is unjustified by the aluminum producer and we believe has only been assumed by him in the absence of satisfactory instruction from our own industry. The welded fabrication of aluminum offers us an opportunity to enlarge our market, and we bespeak the united support of the aluminum producer in recommending oxyacetylene to the exclusion of oxyhydrogen as promoting the best interests of the aluminum fabricator, the aluminum producer and the welding industry. The oxyacetylene welding of aluminum is metallurgically right and economically sound.

Synopsis and Conclusions Paper on Tests of Riveted and Welded Steel Columns

By **WILLIS A. SLATER** *and* **M. O. FULLER**

†W. A. Slater, Research Prof., Eng. Materials, and Director, Fritz Eng. Laboratory, Lehigh Univ., Bethlehem, Pa. died on October 5, 1931. M. O. Fuller is Associate Prof., Civ. Eng., Lehigh Univ., Fritz Eng. Laboratory, Bethlehem, Pa. This paper was published in the Sept. 1932 issue, Proceedings, American Society of Civil Engineers.

Synopsis

THE tests reported in this paper were undertaken to secure a comparison of the behavior and strength of built-up steel columns fabricated by riveting, with similar columns fabricated by welding. The program included nine columns, of which two were riveted and seven were welded. In four of the welded columns, the welding was continuous throughout the length. In the other three welded columns, intermittent (or stitch) welding was used. The lengths (to the nearest inch) were 19 ft. 8 in. for three of the columns, 16 ft. 6 in. for two, 15 ft. 5 in. for three and 5 ft. 6 in. for one.

Table 1—Data of Test Columns

Column No.	Type	Length in Inches	Core	Plates Width in Inches	Plates Thickness in Inches	Sectional Area of Column in Square Inches	I in Inches⁴	r in Inches	$\frac{l}{r}$	Average Stress at Maximum Load, in Kips* per Square Inch
1	Continuous weld	236	8-in. H, 32-lb.	12	5/8	24.30	206.6	2.92	80.8	32.3
1*BB*	Continuous weld	236	8-in. H, 32-lb.	12	5/8	24.30	206.6	2.92	80.8	32.3
2	Riveted	236	8-in. H, 32-lb.	12	5/8	24.30	206.6	2.92	80.8	32.5
3	Continuous weld	198	10-in. I, 35-lb.	11	5/8	23.97	155.0	2.54	77.9	30.8
4	Continuous weld	184.5	10-in. I, 25.4-lb.	11	5/16	14.26	78.6	2.35	78.7	36.9
5	Riveted	185	10-in. I, 25.4-lb.	11	5/16	14.26	78.6	2.35	78.7	35.8
6	Stitch weld	198	10-in. I, 35-lb.	11	5/8	23.97	155.0	2.54	77.9	33.3
7	Stitch weld	184.5	10-in. I, 25.4-lb.	11	5/16	14.26	78.6	2.35	78.7	36.7
8	Stitch weld	65	10-in. I, 35-lb.	11	5/16	17.10	77.8	2.12	31.1	†

* One kip equals 1,000 lb. † Not tested to failure.

The columns were built up by riveting or welding cover plates to the H-section or the I-section which formed the core. The total cross-sectional area ranged from 14.26 to 24.3 sq. in. in different columns. All were tested as flat-ended columns. Observations included measurement of strains, slip of plates, deflection of column due to the applied load and strains caused by plastic flow of the heated metal and by the stress set up when the heated metal cooled. In general, the strains were measured in various positions in cross sections at the top, middle and bottom of the column. These observations gave the basis for determining the bending moment distribution between the ends and the center of the column. Tension test coupons from various positions in the cross section were used to determine the variation of yield point stress throughout the section.

A special feature was the testing of the column having an excessive initial curvature for comparison of strength, bending moment and deflection, with those of a similar straight column.

Summary of Results

The results of this investigation may be summarized in the following eleven items:

1. The largest slipping of plates shown by the measurements was about 0.001 in. Even this may have been merely a difference in compressive deformation within the gage length over which the measurements were taken. No weaknesses attributable to slipping of plates developed.

2. Stitch welding caused shortening of the metal at sections through the welds and elongation at the edges of the cover plates at sections midway between welds. In the stitch-welded columns, the strain lines appeared first on the sections through the welds, but none appeared in the welds or in the metal very close to the welds. In general, they did not appear between the welds except in the webs of the columns, where their formation apparently was brought about by initial compressive stresses set up in the cooling of the section after rolling.

3. The points of first appearance of strain lines corresponded in position to the points of highest stress due to heating of the metal, as far as the stress due to heating could be determined.

4. The average modulus of elasticity determined from the coupon tests was 29,300,000 lb. per sq. in., and that determined in the tests of the columns was 28,650,000 lb. per sq. in. The modulus used in computing stress from strain was 29,000,000 lb. per sq. in.

5. In all comparable cases the deflections were greatest for the continuously welded columns. There was little distinction as to deflection between the riveted and the stitch-welded columns. In general, the magnitude of the deflection corresponded to the magnitude of the initial departures from straightness. However, only one column of a kind was tested, and the differences in deflection are not large. Therefore, conclusions as to deflection should be used with caution.

6. In Columns Nos. 3, 4 and 5, the bending stresses and, therefore, the bending moments were about equal at top, middle and bottom. In the other columns the position of maximum moment varied between top, middle and bottom. Nothing in the tests indicated any marked advantage of either riveted or welded columns over the other as far as freedom from bending moments is concerned, although the continuously welded columns seemed to be more subject than the others to initial deflection.

7. In spite of its large initial deflection, Column No. 1, which was continuously welded, carried slightly greater maximum load than its counterpart, Column No. 1*BB*. The bending moments in this column, computed as the product of the loads times the deflections relative to the line of action, agreed fairly well with the moments computed from the measured strains. The deflections computed from the bending moments also agreed very well with the measured deflections.

8. The limit of proportionality between applied stress and resulting strain occurred at stresses well below the yield point, but higher than the stresses at which strain lines first appeared. There was, however, a general correspondence between the stress at the limit of proportionality and that at which strain lines first appeared, and this suggests that both were influenced by the presence of initial stresses in the columns.

9. The ratios of the stress at maximum load to the yield point stress determined from the coupons were so nearly equal for all the columns tested, that no reliable distinction can be made between the merits of riveting or welding columns, either with continuous or an intermittent weld.

10. Although the tests indicated the presence of initial stresses of considerable magnitude, introduced in the cooling after welding (and probably after rolling also), the maximum loads carried did not appear to be appreciably influenced thereby.

11. The average stress at maximum load was about 15% greater than the strength computed by the Rankine formula, Equation (1).

Welding with Copper Alloys

By G. T. PIERSOL

†Presented at November 17th Meeting of Los Angeles Section, A. W. S., by G. T. Piersol, Sales Engineer, American Brass Co.

WELDING with copper alloys is generally called "bronze welding." This is a very broad term. The word "bronze" is very indefinite as to what base metals and proportion of each is used in the manufacture of the bronze alloy. Many of the copper alloys now in common use called bronzes are really brass (copper and zinc). An alloy of copper and tin is known as a true bronze, although there are many alloys called bronzes which contain no tin. There are a large number of mixtures of brass alloys and of bronze alloys whose properties cover a wide range. We have, for instance, copper alloying with tin, zinc, nickel, manganese, silicon, aluminum, silver, iron, phosphorus, cobalt, gold, oxygen and several others. Zinc and copper, for instance, make no less than fifteen different alloys, all in common use under different names, and all more or less distinctive in physical and chemical properties, and when we come to combine two or more of these elements with copper, we obtain several hundred alloys, which are in more or less common use.

After thorough study and research, it has been found that certain copper-tin, copper-zinc and copper-tin-zinc alloys have proved satisfactory through the years.

Copper is by far the most important of the three metals referred to. Its melting point of 1981° F. is within convenient reach of any of the usual welding methods. But the welding characteristics of copper may be more clearly understood if we consider the method used in the manufacture of copper.

Copper is usually received at the refinery as rough, flat slabs called "anodes." The anodes contain appreciable proportions of metallic impurities. These impurities are taken out by the electrolytic process whereby the copper anodes are hung in a plating bath and the copper transferred to a sheet copper cathode by the usual electroplating process. These cathodes of nearly pure copper are then melted up in a large reverberatory furnace from which they are cast into slabs and bars for making sheet copper, copper wire, etc.

Copper at normal air temperatures is unaffected by the oxygen of the air, but at the heat of the reverberatory furnace an appreciable amount of the copper is oxidized and the oxide dissolved in the molten copper. In order to reduce the oxide, green poles are thrust into the bath, the oxygen going off with the hydrocarbon from the wood. This process is never carried far enough to rid the molten copper of all of its oxygen. There is always left in electrolytic copper 0.03 to 0.07 of 1% of oxygen in the form of cupric oxide. It is this small amount of oxygen that is the distinguishing feature of electrolytic copper. This amount of oxygen has little effect upon the electrical or physical properties of copper products. But, when we come to weld it, the cuprous oxide does give us trouble in two ways. First, the cuprous oxide has a melting temperature slightly below that of pure copper. Hence, when electrolytic copper is heated near to its melting point, the cuprous oxide has already melted, and any distortion, occasioned either by shrinkage or mechanical working, will cause cracking.

When the electrolytic copper has been welded, the cuprous oxide (now increased slightly by the welding process) spreads out along the grain boundaries so that a small amount will make a serious line of weakness. Thus, even though the weld be quite sound, rarely do we obtain a strength of weld greater than 50% of that of the wrought electrolytic copper.

A second source of weakness arises as a result of the cuprous oxide, but in a different way. If the weld be made in a reducing atmosphere, such as the hydrogen and carbon monoxide of the oxyacetylene torch, the cuprous oxide on the contact surface is reduced to sponge copper which has little strength.

This action would give little trouble if the effect were all on the surface. The proper weld rod would alloy with the sponge copper and give us adequate strength. Hydrogen, however, has the facility of penetrating into the red-hot copper several thousandths of an inch. Encountering the cuprous oxide, the usual reduction action takes place and sponge copper and water vapor are formed. The water vapor lacks the faculty of diffusing through the red-hot metal that is possessed by the hydrogen. Hence, pressure is created tending to disrupt the copper. Stresses thus produced may remain after the copper cools and cause weakness.

Not a few welders are under the impression that if they use the correct weld rod and flux on electrolytic copper sheet that they will obtain a strong bond. Numerous patents have been taken out on weld rod material with this in mind. Some of these special rods carry appreciable amounts of silver. But, whether the electrolytic copper is used as a weld rod or as the base metal, or as both, one of the other of the above described weakening effects is apt to obtain. We cannot expect a weld in electrolytic copper to develop more than 15,000 lb. to 18,000 lb. per sq. in. tensile strength.

There are several exceptions to the above statement, however. Some recent tests made on resistance butt welds indicate a high strength approximating that of soft wrought copper. In this case, the atmosphere is excluded from the weld metal. A strength of from 23,000 to 28,000 lb. per sq. in. was obtained in the above tests.

Another way in which the trouble with electrolytic copper welds may be avoided is by the use of brazing solders which melt at approximately 1560° F. If the work is carefully done, the brazing solder is melted and alloyed with the copper at a temperature which does not disturb the distribution of the cuprous oxide. Hence, a good strength is obtained.

Finally, use may be made of silver solder, which melts still lower (about 1420° F.). This temperature does not affect the distribution of the cuprous oxide.

Deoxidized copper is a copper from which the cuprous oxide has been removed by some deoxidizing agent. The agents usually employed for this purpose are phosphorus, silicon, calcium, boride, zinc or cadmium. An excess of the deoxidizer is used and a small amount remains in the copper.

Copper deoxidized with any of the above elements will weld with greater facility and the weld will have nearly twice the strength of a similarly made weld in electrolytic copper. It is, therefore, advisable, in all cases where mechanical strength in the weld is desired, to use deoxidized copper. Even when the weld is made in electrolytic copper itself it is better to use a deoxidized copper weld rod.

Everdur metal, a copper-silicon-manganese alloy, is easily the most weldable of the high copper alloys. Everdur contains approximately 96% copper, 3% silicon, 1% manganese. It is a high strength engineering material with a strength equal to medium carbon steel when hot rolled into sheets and plates, and exceeding that of medium carbon steel when cold rolled or drawn into sheets and rods.

It is immune to rust and is better than copper in resistance to other forms of corrosion.

In present-day production, welded construction is rapidly replacing the older, more tedious and more costly methods of fabrication.

Everdur possesses excellent welding characteristics and is readily welded by the oxyacetylene, metal or carbon arc and resistance methods and, for all other fabricating operations, is worked by the same methods and equipment used with steel. Everdur tanks of welded construction are in service today in various sizes up to 20,000 gal. capacity. The majority of the larger tanks now in service are of welded construction.

Twenty-seven nationally distributed automatic hot water storage heaters are available, equipped with Everdur tanks. The majority of these tanks are of all-welded construction. Everdur welding rods are used for this work.

Everdur welds, machined flush, have a tensile strength of about 85% of that of the parent metal. With the reinforcement bead left on, the welds will equal or slightly exceed the parent metal in strength. Resistance welds on thin sheets cool so rapidly that there is practically no difference in the strength of the seam and of the sheet.

Everdur welding rods show remarkable penetration when used on steel and, for this reason, it is possible to weld Everdur inserts in steel plates used for the construction of electrical equipment. Everdur welding rods are being used successfully with the oxyacetylene process to fabricate metal furniture and similar products. With Everdur welding rods no flux is required in tack welding thin clean sheets of steel and no difficulties are encountered in applying standard painted and enameled finishes over the welded surfaces.

Strengths of 50,000 lb. per sq. in. or better are readily obtainable in any thickness of Everdur plates or sheets with excellent ductility. Everdur is not, however, fool proof any more than is steel.

In working out a welding procedure, the first objective is sound weld metal with perfect penetration or bond to the base metal. Secondly, the nature of the weld metal and means of improving same by such auxiliary operations as peening and annealing must be considered.

Everdur should be *welded as rapidly as possible.* The reason for this is that it is desirable to keep the shrinkage stresses in the red-hot metal as low as possible and, of course, the best way to avoid them is to cut the heat flow into the base metal as short as is consistent with good union. This rule holds whether the welding be done with the oxyacetylene torch or the electric arc. Moreover, the most homogeneous solution the metal can have is that of its liquid state. Hence, the quicker the metal is solidified, the more uniform will be the cold metal and the finer its structure.

A flux is not absolutely necessary for welding Everdur to Everdur, or Everdur to steel, but a light sprinkling of a dry flux improves the flowing qualities of the metal. It is more necessary with the oxyacetylene torch than with the arc. The best flux thus far developed is that made from 90% fused powdered borax and 10% sodium fluoride, used dry or in alcohol free from water.

For welding sheets, square edges are used up to $\frac{1}{8}$ in. in thickness and the edges beveled for thicker sheets. For thick sheets, $\frac{1}{2}$ in. and above, a single 90° V-groove, a double 90° V-groove or a U-groove may be used.

For thin sheets, $\frac{3}{16}$ in. and under, the cooling from the welding temperature is so extremely rapid as to give excellent strength and ductility in the weld metal, but where maximum strength and ductility in the welds in thick sheets is desired, each successive bead should be thoroughly peened to a depth of approximately 0.2 in., then anneal the cold worked metal at a dull red temperature (about 1112° F.). In annealing welds with the torch always start the heat at some point other than the end of the seam. If started at the edge, a crack may result, due to tension at the edge when the torch is moved inward.

In the use of oxyacetylene torch, a slightly oxidizing flame should be used in order to secure as good concentration of heat as possible, with a maximum rapidity of welding. A flame about 5 in. long with a very short tip gives uniformly good results.

A metal having the properties of Everdur has long been desired for the manufacture of pressure vessels, and it is being used for many purposes on account of its high strength, high resistance to corrosion, high fatigue limit and weldability.

Another new weldable alloy produced by the American Brass Company is known as Everdur No. 9, which is intended for an entirely different purpose than the regular Everdur alloy.

Everdur No. 9 contains approximately 57.50% copper, 42% zinc and 0.50% manganese with a trace of silicon and is being used for making architectural shapes.

The principal advantages of this new alloy are that it can be extruded into intricate and irregular shapes and, at the same time, can be welded with a rod of the same alloy as the parent metal.

The welding feature is important because manufacturers of architectural bronze work can now use this method for fabricating such construction as windows, doors, grilles, etc., where heretofore, it was necessary to join the individual shapes by either silver soldering or with the use of screws and bolts, both of which entailed greater labor and expense.

Everdur No. 9 can be fastened together so that the joint will not show, and with very little, if any, sacrifice in strength, as tested welds show a strength of 90 to 95% of that of the base metal.

Simple shapes of this material will show a tensile strength of about 63,000 lb. per sq. in. It is not recommended for mechanical shapes or other uses subject to high stresses. This material is also obtainable in the form of plates and sheets.

Everdur metal No. 9 is suitable for gas welding only, as the zinc content is too high for satisfactory electric welding. Extruded architectural Everdur No. 9 should find wide use in the building industry, especially for windows and window frames. Steel used for windows rusts and requires frequent painting which is expensive.

Brass is readily welded by the oxyacetylene torch. As in the case of the bronze, a good flux is necessary. It is not possible to use brass as a metal arc electrode nor to weld brass sheet with metal electrode of another metal, on account of the rapid oxidation of the zinc it contains.

However, an excellent weld is frequently obtained by laying a 5% phosphor bronze or a silicon manganese bronze rod on the joint and fusing it with the carbon arc, the carbon being the negative electrode.

Brass sheet, tubes and shapes may be welded with rods of the same composition. A still better method is in the use of a lower melting point material in which case the brass need not be melted at all. Thus, a high strength yellow bronze, such as Tobin bronze, which

melts at 1625° F., will alloy readily with a brass sheet only at a dull red heat. Manganese bronze, an alloy of copper, zinc, manganese and iron, melts at a slightly lower temperature (1598° F.). Phosphor bronze can be used if it is desired to match the color of the commercial bronzes (90% copper—10% zinc).

Welding of brass and copper pipe is coming into more general use. A recent installation of 300,000 lb. of Anaconda 67 brass pipe was made in the new University of Montreal. All sizes from $2^1/_2$ in. to 6 in. were welded. Tobin bronze welding rods are frequently used for this type of work.

Tobin bronze is by far the most satisfactory metal for general oxyacetylene welding. It is applicable to welding all of the brass mixtures, nickel silver, steel, cast iron, copper, deoxidized copper, monel metal, etc.

Tobin bronze alloy was patented in 1876 by John A. Tobin, of the U. S. Engineering Corps. Its composition is approximately 60% copper, 1% tin, 39% zinc. This welding rod is found in nearly every welder's stock rack. Its excellent qualities for general welding purposes are well known, and it has stood the test of many years in actual use.

Manufacture of Ordnance at Watertown Arsenal Revolutionized through Arc Welding*

By MAJOR G. M. BARNES

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MODERN welding had never been used in the construction of gun-carriages by the Ordnance Department, United States Army, until the work described here was undertaken at the Watertown Arsenal. In fact, there was a strict ruling against the use of any welding whatsoever in connection with gun and gun-carriage work. It was considered that welding was not only an unsatisfactory method of construction, but dangerous, as practically all parts of the carriages were called upon to resist large impact forces.

It would be difficult for one not familiar with Ordnance practice to appreciate the dependability which must be built into a piece of Ordnance. The requirements for strength and long life are usually far beyond those which would be considered satisfactory for commercial machines. The reasons for this are readily understood when it is considered that Ordnance in war must function under the most adverse conditions in the field where repairs are exceedingly difficult, if not impossible, to make. A single malfunction due to a weak or defective part may result in the death of several men. If a piece of artillery goes out of action for a few minutes, due to a mechanical fault, its whole value may be lost. This would not condemn most commercial machines which could be repaired and put to work.

The 3-in. antiaircraft mount (mobile) shown in Fig. 1 was selected as the best carriage to test the possibilities of welding gun-carriages, for the following principal reasons:

It represented the most modern type of post-war gun carriage, which had been standardized by the United States Army. This carriage was under production at Watertown Arsenal. It was of the mobile type, i.e., on wheels, and its members were subject to severe road shocks in addition to the impact forces due to firing. The principal parts of this carriage were highly stressed and of intricate design. The 3-in. antiaircraft mount, which was originally made almost entirely of cast steel, had passed all tests, had been standardized, manufactured and issued to the service prior to the substitution of welded parts. It was felt that if a success could be made of welded parts for this carriage there would be little question concerning the successful application of welding to other types of artillery.

The 3-in. gun-carriage is shown in the traveling position in Fig. 2. It is folded so as to form as compact a traveling load as possible. The unit is trailed over roads and across country behind a suitable prime mover. Although weighing 8 tons, the carriage can successfully travel at speeds up to 40 miles per hour, without damage to the various mechanisms.

Figure 1 shows the unit in the firing position. The front and rear two-wheel bogies have been removed and the mount lowered to the ground by means of screw-jacks built into the carriage. The long arms, called

* This is a brief of a paper by Major Barnes which was awarded second prize in the Second Lincoln Arc Welding Prize Competition sponsored by The Lincoln Electric Company, Cleveland, Ohio. Major Barnes was awarded $3500 for his paper and in its original form it consists of approximately 100 pages of typewritten description, data and photographs. The complete paper with other prize-winning papers will be published in book form by the Sponsors.

Fig. 1—The 3-In. A. A. Mobile Gun in Firing Position

Fig. 2—The Same Gun Ready for the Road. Note How Folded Outriggers Form the Trailer Body

outriggers, in this position have been opened and stand at 90° to each other when flat upon the ground. The mount is so designed that, although it is not anchored to the earth in any way, it will not move or lose its orientation when the gun is fired rapidly.

The pedestal was also made of cast steel. The four main outriggers are secured to the pedestal by means of heavy pins, which permit these outriggers to swing in a horizontal plane. They can thus be folded together to form the trailer body. Each outrigger is in three sections, which are folded when traveling. The main outriggers, at first, were made of cast steel, then of cast steel ends to which I-beams were riveted. When traveling, the gun-carriage is supported by two-wheel bogies. Two half elliptic springs are mounted on each bogie axle. The springs, in turn, are secured to the bogie frames, which were also originally of cast steel. In addition to these main members there are also the elevating and transversing mechanisms which are used to give the gun the required elevation and angle of traverse or direction. In all, there are 1211 different parts used in the construction of this carriage, but only the principal ones will be described.

The top carriage directly supports the gun with its recoil and recuperator mechanisms. It is called upon to take the direct shock of the discharge of the gun and to transmit this load through the pedestal and outriggers to the ground. The gun swings through the two main arms of the top carriage, its elevation being controlled by the elevating mechanism secured to the top carriage.

This component was originally designed as a one-piece casting of $^1/_2$-in. section with the lower stem integral.

Important steel castings, such as the top carriage, are thoroughly X-rayed at Watertown Arsenal before being accepted for use as gun-carriage parts. Many of these castings when X-rayed were found to have shrinkage cracks, sometimes in the main arms and sometimes near the trunnion supports. The number of rejections became alarming.

In attempting the redesign of the top carriage it was, of course, necessary that the new part have the same general exterior contour as the cast steel top carriage, in order that no other adjacent members would require modification. It was decided to use a medium carbon steel plate $^1/_2$ in. thick, which would produce a top carriage of about the same weight.

A number of these welded steel top carriages were then constructed, assembled to carriages under manufacture and issued to the Proving Ground and Using Service for tests. All of these top carriages were found to be satisfactory and passed all tests. There were no failures.

These experiments convinced the writer that this member could be successfully made of $^1/_4$-in. nickel steel, thus securing an important saving in weight. Weight saving is of great importance in mobile gun-carriages, as it is in the case of mobile commercial vehicles and machines.

An experimental top carriage of $^1/_4$-in. nickel steel was next designed and built. The construction followed that of the $^1/_2$-in. welded top carriage except that light forged caps welded to supporting ribs were substituted for the separate forgings at the trunnion bearings and a stem of drawn seamless tubing was used.

When completed, the relative weights of the cast steel and the welded top carriage of $^1/_4$-in. nickel steel were as follows:

Cast steel	975 lb. (in rough)
Welded $^1/_4$-in. nickel steel	607 lb. (in rough)
Saving in weight	368 lb. (or 37.7%)

This welded top carriage is shown in Fig. 3. The pedestal for this carriage was originally of cast steel of about $^1/_2$-in. section. The physical requirements of the cast steel for this part were the same as for the top carriage. This was not as difficult a steel casting to make as the top carriage. Many of these castings, however, were found to be warped, especially the two pointer-like projections at the base, which were often curled upward. This made it sometimes very difficult to lay out the casting and to so shift the center lines that it would clean out. The pedestal was the next part of this carriage to be considered for welding after a success had been made of the welded top carriage. It was decided to go the limit at once in the design of this part, in making it of the lightest possible material consistent with strength and rigidity. For the sides of the pedestal, $^5/_{32}$-in. nickel steel plates were selected, while $^1/_4$-in. and $^1/_2$-in. nickel steel plates were used for other parts.

The relative weights of the cast and welded pedestals shown in Fig. 4 were found to be as follows:

Cast steel pedestal (finish machined)	1115 lb.
$^5/_{32}$-in. and $^1/_4$-in. nickel steel pedestal (finish machined)	823 lb.
Weight saving	302 lb (or 27%)

The intermediate and outer outriggers are folded so as to lie above the main outrigger when traveling. When the carriage was first built the inner and intermediate members were made of cast steel of the same quality as

Fig. 3—Welded Top Carriages Made from ¼-In. Nickel Steel

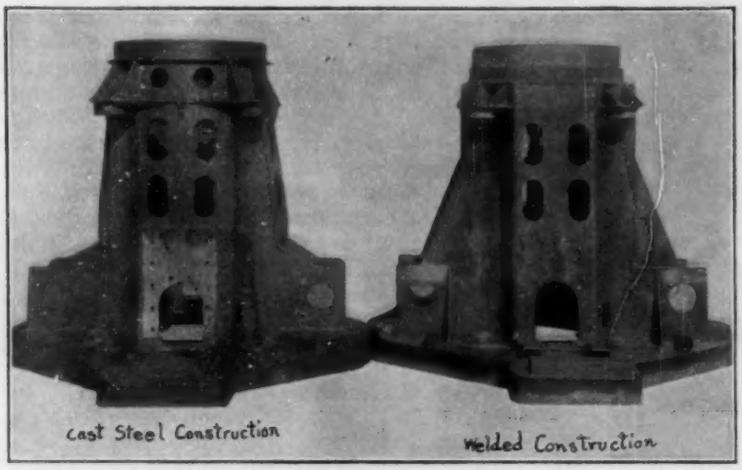


Fig. 4—At the Left Is Shown the Old Cast Steel Pedestal. The Welded Design Is Shown at the Right

used for the top carriage and pedestal. The outer member was constructed of cast steel ends to which steel plate was riveted.

While the cast outriggers were found satisfactory, it was thought that at least the inner outrigger could be improved by using cast steel ends to which an I-beam section was riveted. This was tried but without any material saving in weight or cost.

The next move was to reduce the weight of these outriggers by using heat-treated, aluminum alloy castings, redesigning them to obtain the requisite strength and rigidity.

These outriggers have again been redesigned using $^1/_4$-in. and $^5/_{32}$-in. nickel steel plates and will soon be placed under production. The requirement of keeping the weight within that of the aluminum alloy outriggers has been met to all practical purposes. This is possible, when it is considered that nickel steel has a proportional limit nearly four times greater than cast heat-treated aluminum alloy while the modulus of elasticity of steel is also three times that of aluminum. The weights of the cast steel, built-up, aluminum and welded outriggers follow:

Member	Weight of Cast Steel, Lb.	Cast Steel Welded to I-Beam, Lb.	Weight of Aluminum (195 H4), Lb.	Weight of Welded Nickel Steel, Lb.
Main outriggers	2660	2500	1765	1668
Intermediate outriggers	1360	..	680	800
Outer outriggers	720	..	400	540
	4740	2500	2845	3008

While the aluminum outriggers have given satisfactory results in service, it is felt that the nickel steel outriggers, the first set of which has recently been completed and tested, are superior when it is considered that the elongation of aluminum alloy is but 6% as compared to 18% for nickel steel. In the event of an accident such as the overturning of the carriage which might produce stresses above the normal, an aluminum outrigger might snap, while the nickel steel beam of the same strength probably would bend and could be straightened and used again.

A study of the bogie frame indicated that it could be made an integral unit by using welded nickel steel plates, thus eliminating all the machining previously required to permit the five separate castings to be joined together. The weights of these frames are as follows:

	Front Bogie Frame, Lb.	Rear Bogie Frame, Lb.
Cast steel	590	558
Welded nickel steel	430	380

This frame illustrates very nicely one of the advantageous characteristics of welding; that of making it possible to weld separate members into a unit, thus eliminating all intermediate machine work which was formerly necessary to permit the separate castings to be assembled.

Due to the success of welding guides on the gun, a new type of cradle made of welded steel plates has been designed for this carriage. This cradle, which is now under construction, is shown in Fig. 5. One of the principal advantages of the welded cradle will be lightness. The relative weights of the two cradles are as follows:

Cradle of cast steel, unfinished (actual wgt.)	588 lb.
Wgt. of welded nickel steel cradle (computed)	330
Estimated saving in weight	258

Welding, as a result of this pioneering work which has been done at Watertown Arsenal, has become so well established as a process of manufacture, that several new types of Ordnance have been built recently, in which welding was adopted at the outset so that the parts were designed originally as welded members. When this is done the welded parts are invariably lighter, less complicated, more easily fabricated and considerably cheaper.

In considering this 3-in. antiaircraft carriage, it must be borne in mind that this unit was originally designed as a structure to be built of cast steel members and that the welded members followed closely the design of the steel castings, which they replaced. It would be advantageous now to redesign this carriage from the ground up, on the basis of using welded steel members throughout. Such a replacing carriage would be very much simpler, would permit of more rapid production and, hence, would be very much cheaper.

In this work it has been found that designs can be made of welded members which would have been impossible if cast components had been employed. Our experience has shown that welding opens an entirely new field to the designer of Ordnance material, which will have a very far-reaching effect on the Ordnance of the future.

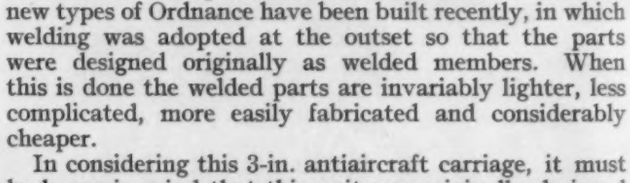


Fig. 5—Welded Cradle for Gun with Welded Guides

FROM ABROAD

Oxyacetylene Construction of Apparatus and Containers

✦Published by The International Advisory Committee for Carbide and Welding Technique, Geneva.

Methods of Welding

THERE are two alternative welding methods which may be adopted for the construction of apparatus and containers, namely, hand or machine welding. Hand welding is most generally used. Machine welding, with or without filling material, is an excellent process for production on a large scale. The superiority of the oxyacetylene welding seam is due to its permanence and ductility. Hand welding has recently been supplemented by the use of multiflame blowpipes, which save considerable time.

Either the right-hand or left-hand method of welding may be used. Seams welded by the right-hand method have greater density and fewer slag inclusions. Right-hand welding may be used for either longitudinal or circular seams. Expert welders are able to extend this process to vertical, horizontal and vertical fillet seams. Right-hand welding saves a considerable amount of time, especially in the case of fillet seams. By this method plates up to $^5/_8$ in. thick can easily be welded with one continuous seam, the edges being previously prepared by chamfering to 60° with a cutting blowpipe. When plates thicker than $^5/_8$ in. are welded by the right-hand method, the filling material is deposited in two layers. The first layer should be about 4 in. long and is followed by a similar layer on top of it which brings the weld to the required thickness. This process is repeated until the whole seam is completed. If the joint is accessible on both sides, the single Vee-seam is often substituted by a double Vee-seam which is simultaneously welded on both sides in a vertical position. The advantage of this method lies in the speed with which it may be executed. It is necessary to select a smaller blowpipe than is generally used for a similar thickness in order to prevent overheating. It should be specially noted that the joint must be prepared so that one weld penetrates about $^2/_3$ of the metal and the other $^1/_3$. The deep side of the seam is started first and is then followed up and completed by the second welder who must take special care to heat the metal thoroughly so that an actual refinement of the grain takes place. In carrying out this kind of work the first welder must always work sufficiently ahead of the second one to allow the first deposit of weld metal to cool down sufficiently to benefit fully by the normalizing effect of the second weld. The usual distance between the two welders is from 8–10 in. The advantage of the above method of uneven double V-welding is very apparent, and by this method the most favorable welds are obtained.

In the case of thicker plates, the filling material is usually hammered while warm. Pneumatic tools are often used for this purpose. The welder manipulating the flame steps quickly aside and his helper immediately hammers the welding seam with a pneumatic hammer. As the actual welding, this process is also carried out simultaneously from both sides. Welds carried out in this manner possess every characteristic of the parent metal.

The Technique of Welding

The growth of oxyacetylene welding has established a number of technical rules which form the groundwork of successful and constructive application. Up to the present, unfortunately, a collection of these rules has not been universally obtainable.

Welding Cylindrical Vessels.—The normal welding seam is suitable for cylindrical vessels for liquids and low pressure gases, and these present no difficulty in construction. Edges of thin sheets (up to $^1/_{16}$ in. thick) are usually flanged before welding and are then melted down to form a strong weld without filling material. This method is also adopted for welding end plates. The flanged end plates are pushed into the welded shell and the projecting edges are welded together. First, in order to ensure true alignment of the ends, the mouth of the shell is slightly belled out for a depth of about $^3/_4$ in. The convex ends are then dropped in and the edges of the shell beaded over them and the joint completed by welding. Barrels for the transport of grease and oils are constructed by autogenous welding, as the welding seams, on account of their ductility, permit of strengthening grooves being rolled in the cylindrical portion of the barrel.

Welding Rectangular Vessels.—Corner seams are generally avoided in the construction of rectangular vessels with thin walls because distortion sets in and the smooth walls become buckled. To avoid this, the plates should be bent in such a manner that the longitudinal seams are situated on the flat surface. Joints in this position are both easier and quicker to weld than corner seams. In the case of plates thicker than $^1/_8$ in., however, corner seams may be successfully made. Owing to their flat walls, rectangular vessels breathe freely, and corner seams are therefore more heavily stressed than seams in the actual walls. This arises in the case of large rectangular silos used for storing grain, when the entry of material is directed against one of the walls. Under these circumstances the corner seam is strengthened by stiffening. In the construction of rectangular vessels ends and lids can be welded on and welded in respectively. Ends can also be attached by means of corner seams. Seams in plates over $^3/_8$ in. thick are frequently welded on both sides.

Welding on Stiffeners.—It is often necessary to weld stiffeners to circular and rectangular vessels. This is a very simple process in the case of circular vessels, as the flat iron rings, junk rings or T-iron stiffening rings, which are welded together, are either pressed or shrunk on and tacked to the shell plate every 6 to 8 in. Where possible, angle rings are attached in such a manner that only the leg of the angle ring lying against the wall is tacked on. Silos, provision vessels and other store containers for liquids frequently require strengthening owing to their large capacity. Outer walls are often stiffened by U- and I-sections, which are tacked to the shell at regular intervals. It is totally unnecessary to heat flat plates before tacking on stiffeners. I-sections and T-sections are superior to U-sections because the tapering flanges are easier to weld. In the case of U-sections it is difficult to tack on the bridge side. Points where stiffeners meet can be welded together without the use of butt straps and reinforcing angles. Thus, the

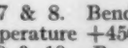
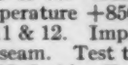
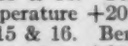
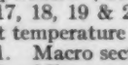
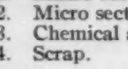
vessel is bound together by a continuous framework through which all the stresses are distributed.

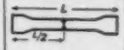
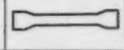
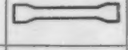
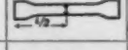
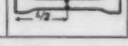
Welding on Flange Rings.—It is possible to construct removable lids and ends by welding on flange and angle rings. In the case of thin materials the angle rings are either pressed on or attached by butt welding. When angle rings are pressed on, only the seam joining the root of the angle to the edge of the vessel is continued right around the circumference. It is only necessary to secure the leg of the angle by tacking it at intervals to the side of the vessel. In the case of metal plates over $^1/_8$ in. thick the rings are generally attached by butt welding. In order to prevent the angle ring from buckling it is stiffened before the welding operation by bolting a second ring to it in order to increase the moment of resistance. Special unequal sections are extensively used, and by this means the high leg effects equal distribution of heat and prevents distortion. In place of angle rings flat iron flange rings may be welded on from the exterior by means of fillet seams. Where great strength is not required it is easier and cheaper to replace the fillet seam by shrinking on a flange ring in a manner to project over the shell by the thickness of the sheet and making a corner weld in the mouth of the shell. In order to economize on bending work, which is expensive, the cutting blowpipe is used for cutting out the flanges in separate pieces from metal plates of the required thickness; these pieces are butt welded together before the complete flange is welded on. It is not always necessary to fix flanges by welding. In that case the flange ring is pressed on and the projecting material of the sides of the container are heated by the

Test Specimens

Nos. 1 & 2. Tensile tests with central welding seam. Test temperature +20° C.
Nos. 3 & 4. Tensile tests under heat with central welding seam. Test temperature +850° C.
Nos. 5 & 6. Bending tests with central welding seam. Test temperature +20° C.
Nos. 7 & 8. Bending tests with central welding seam. Test temperature +450° C.
Nos. 9 & 10. Bending tests with central welding seam. Test temperature +850° C.
Nos. 11 & 12. Impact tests with notch made in direction of welding seam. Test temperature +20° C.
Nos. 13 & 14. Tensile tests on original unwelded plate. Test temperature +20° C.
Nos. 15 & 16. Bending tests on original unwelded plate. Test temperature +20° C.
Nos. 17, 18, 19 & 20. Impact tests on original unwelded plate. Test temperature +20° C.
No. 21. Macro section.
No. 22. Micro section.
No. 23. Chemical analysis.
No. 24. Scrap.

Fig. 1

Test No.	Method of testing	Elastic Limit Tons per sq. inch	Tensile Strength Tons per sq. inch	Elongation in % L = 7½ in.	Reduction of Area %	Temperature at which Bar was tested °C.	Description of fracture
1		15.88	22.5	24.1	68.6	+ 20°	Fracture in the weld
2		15.4	22.2	13.7	23.2	+ 20°	Fracture outside the weld
13		15.0	22.5	30.2	63.5	+ 20°	Bar fractured
14		15.0	22.1	34.3	67.5	+ 20°	Bar fractured
3		2.38	2.91	43.5	96.7	+850°	Fracture outside the weld
4		1.97	2.30	66	98.7	+850°	Fracture outside the weld

Test No.	Method of testing	Impact Test Foot lbs. per sq. cm.	Temperature at which Bar was tested °C.	With or without welding seam
11		100.0	+30°	With
12		94.75	+20°	With
17		121.5	+20°	Without
18		119.5	+20°	Without
19		123.5	+30°	Without
20		123.0	+20°	Without

Chemical Analysis:

Analysis of Metal Plate No. 1
0.067% C, 0.035% Mn.
0.402% P, 0.038% S.

Analysis of Metal Plate No. 2
0.065% C, 0.035% Mn.
0.038% P, 0.035% S.

Analysis of built-up Welds No. 3
0.043% C, 0.30% Mn.
0.026% P, 0.022% S.

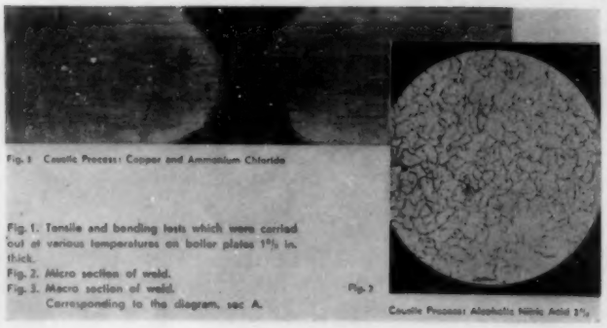


Fig. 1 Caustic Process: Copper and Ammonium Chloride

Fig. 1. Tensile and bending tests which were carried out at various temperatures on boiler plates 1½ in. thick.
Fig. 2. Micro section of weld.
Fig. 3. Macro section of weld. Corresponding to the diagram, sec A.

Fig. 2

Caustic Process: Alcoholic Nitric Acid 2%

welding flame and beaded to the flange. When all unevenness of the flange must be avoided, the flange is not machined until it has been welded on.

Welding on Branch Pipes.—Branch pipes can be welded to circular and angular vessels by means of fillet welds. Difficulty often arises, however, when branch pipes are welded to flat metal surfaces up to $^5/_{32}$ in. in thickness, as the plates have a tendency to buckle. This distortion can be avoided, however, by clamping the branch pipe firmly to the wall. This is done by drawing a screw through the center of the pipe in such a way that a round and thicker plate inside the vessel presses the flat wall firmly against it. Although more work is involved, good results are ensured when welding on branch pipes if the edges of the aperture in cylindrical vessels as well as in angular ones are raised so that the fillet seam is transformed into an ordinary circular seam. This method has great advantages over the one first described. Its adoption is also recommended in the case of flat walls, as the rigidity thus obtained is so great that the possibility of buckling is excluded. Branch pipes which are highly stressed are sometimes pushed through the wall and flanged in warm state on the inside and welded on. The welding seam is thus relieved by the flange. It is often very difficult to flange the shell plates of thick material in the manner described above. The branch pipes are generally fixed in such a manner that a fillet seam is made as well as an internal corner seam, so that the branch pipe is firmly secured. This process is generally adopted for welding branch pipes to thick water-gas welded drums. The seams may be further strengthened by hammering while warm.

When small branch pipes are welded to vessels constructed of thick metal difficulty arises in bringing the thick material of the container and the thin material of the branch pipe simultaneously to their melting point. To facilitate this the thick plate is conically bevelled from the inside by means of the cutting blowpipe. In this way the thickness of the material is equalized at the point of fusion and the operation is carried out without difficulty.

Welding on Brackets.—It is usual to erect and support vessels by means of brackets. Formerly these were cast and riveted onto the vessels. Today they are welded together from separate plates and then welded on. This is the cheapest and most reliable process, as the possibility of leakages is eliminated.

Welding Stiffening Rings to Manholes.—As the moment of resistance of the boiler walls is weakened by cutting out the opening for manholes, this is counteracted by the introduction of stiffening rings. These are welded on by an exterior fillet weld and an additional interior corner seam. This method will be cheaper and more in conformity with welding technique if the thickness of the stiffening ring metal is made to correspond to that of the container, and if the welding can be effected simultaneously on both sides. In the case of vessels subjected to pressure the welding seam can be relieved if a small lip is made on the strengthening ring which lies against the boiler wall on the inside. In this case fillet seams are used.

Welding Vessels Subjected to Pressure.—In many countries the welding of vessels subjected to pressure is restricted, owing to the fact that the existing regulations underestimate the reliability of welding. This is probably due to the fact that the actual workman is largely responsible for the quality of the seam produced. In special cases welded seams are already estimated at 90–100%, so that this work is calculated to arouse confidence. In countries where there are no official regulations the insurance companies are often wary in their authorization of welded seams. Naturally, the construction of pressure vessels and steam boilers should only be undertaken by such firms possessing expert supervisors and reliable, conscientious welders. Riveting is by no means an ideal method of making joints in steam boiler construction, so that the application of welding, which has rapidly increased, will extend still further in this direction. Pressure vessels and steam boilers are mostly constructed from thicker materials. In all cases where it is practical the seams are welded simultaneously from both sides, and the procedure already described should be adopted. The seams are generally hammered off while red hot. This process is even more successful if the finished boiler is heated in a furnace at about 910–930° C. This heating relieves all locked-up stresses in the material and gives the welding seam a fine-grained texture.

In welding pressure vessels and steam boilers only those welding wires should be selected which will give welds of good ductility, having a tensile strength equal to that of the boiler plate.

Data for Calculations

In countries where regulations exist governing the construction of pressure vessels and steam boilers the data for calculations are published. These regulations, however, often underestimate the welding seam, requiring the main seam to be strengthened additionally. The next few years will witness changes in this direction.

It should here be noted that the least ratio of the oxyacetylene welding seam to tensile strength of the whole plate should be estimated at 80% with the use of special welding wire. Oxyacetylene seams hammered under red heat or subsequently annealed at 910–930° C. should have an efficiency of 100%. It should further be impressed upon the authorities to ascertain beforehand the reliability of the welder.

1932 BOUND VOLUME

Bound Volumes of the JOURNAL of the Society for the year 1932 are now available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Also contains Subject and Authors' Index. Price $6.50

HOW TO WELD IT

Repairs to Railroad and Highway Bridges by Electric Welding

By A. G. LEAKE

✦Extract of paper presented at the February 8th Meeting, Cleveland Section, A. W. S. Mr. Leake is President of the Leake and Nelson Company.

SINCE steel has been used in bridges and viaducts, it has been joined by rivets, bolts or pins and no one has departed from these methods until recently. It is only within the last decade that electric welding has been applied to structural steel repairs or used to any extent in the erection of new structures.

Although the application of arc welding to this class of work is new, it has rapidly come to the front and is today a recognized method of making bridge repairs. In many cases it enables the bridgeman to make needed repairs which he could not make otherwise and at the same time effect a distinct saving in the cost of his work.

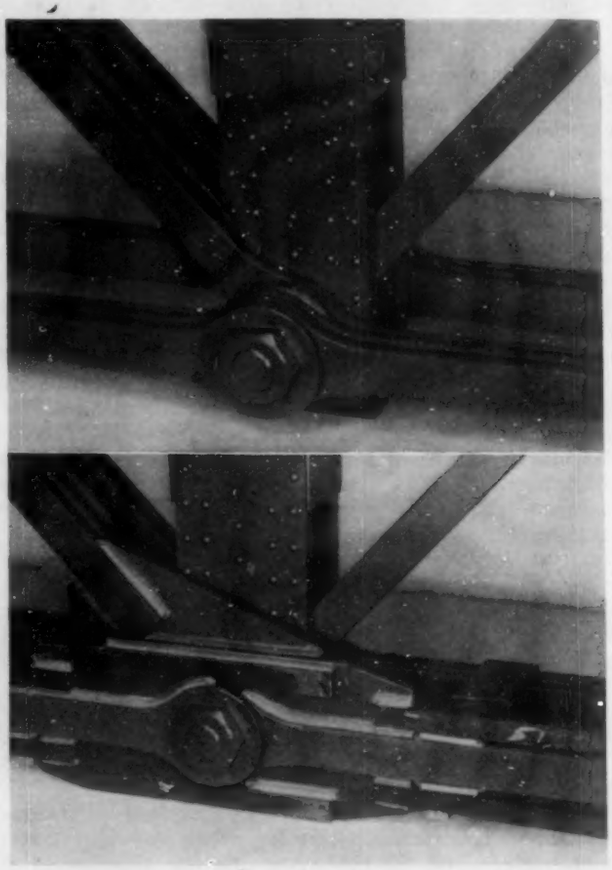
Few engineers who are responsible for the maintenance of bridges are familiar with the recent developments in the rapidly growing field of structural steel repairing by electric welding. They, with all their other problems of painting, masonry work, deck repairs and track work, do not have time for research and cannot be expected to be familiar with the new applications of arc welding.

Most pin-connected bridges were built at a time when railroad rolling stock was lighter than it is now—when loadings of Cooper's E40 were considered heavy. Railroads are now using much heavier equipment than these bridges were originally designed to carry. In many instances loads equivalent to Cooper's E60 or E70 or heavier are being used, thus subjecting these bridges to 50% greater stresses than they were originally designed to carry. This compels railroads to operate their trains at greatly reduced speed in order to lessen impact and resulting unit stresses. Such a reduction in speed may become a serious handicap to the successful operation of a railroad at some strategic point.

I have developed a method of repairing and strengthening weak or corroded joints in pin-connected eye-bar bridges and at the same time building up additional bearing on pins without the use of false work. A solution of this problem has long been sought by engineers.

The plates are assembled at the weak joints and so arranged to overlap one another that by proper welding they will develop the required strength. The size of the plates, required lap and amount of welding depend on the size of the eye-bars and pin. In most instances the eye-bars are packed on the pin so closely that it is impossible to obtain additional bearing on pins. This is not necessary, however, as the plates at the joint are

Bridge Joint Bef ore Strengthening



Joint After Being Strengthened by Welding

so designed that stresses are transferred through plates, thereby relieving bearing on pins. If the section of the eye-bars is reduced by corrosion, it is a simple matter to reinforce the bars to the required strength by welding plates to the bars.

The fact that the joint is made rigid after the plates have been welded in place does not detract in any way from this method of repairing or strengthening as the plates can be made large enough to take care of any secondary stresses which may occur due to any fixation at joint. A study of these secondary stresses in each bridge should be made, and strengthening modified accordingly.

An inspection of old pin-connected bridges further reveals the fact that in almost all cases no motion at joints has taken place in recent years. They are, therefore, to all intents and purposes, fixed and rigid at the present time. Therefore, repairs as outlined above will actually improve these structures by reinforcing them in such a way that secondary stresses are cared for.

It is a simple matter to reinforce these old structures by welding on new material. It is of vital importance that where there is considerable dead load on structures the new material should be added in such a way that it will take its proportionate share of the combined live and dead loads. This I accomplish economically by my method of prestressing material by heating the plate or bar to a specified temperature, fixing both ends by welding and then allowing the plate to cool. This produces in the plate a stress directly proportionate to the amount of elongation caused by the application of heat. Few people actually know that prestressed reinforcing

material may be applied to heavily loaded structures without false work in the manner described above. Such a procedure was followed in repairing the roof girders of a large railway underpass in New York City, saving the railroad approximately $330,000.

Corroded rivet heads can now be repaired without the necessity of cutting out and redriving these rivets. Corroded eye-bars and worn pin bearings in pin-connected bridges may be repaired without false work and made good for stresses far in excess of those originally provided for.

Railroad transfer bridges are another type of structure which are subjected to very severe usage and unusual stresses and strains. I have successfully reinforced and repaired this type of bridge by welding additional plates to chords and other portions of the structure where serious structural defects have developed. End shoes have also been repaired in a similar manner. These bridges have now been in service several years and have shown no signs of failure and have required little or no maintenance.

Excessive wear on pins and pin joints has been successfully repaired by the use of semicircular shims inserted in the pin joints and then welded in place. This repair work was accomplished without the necessity of false work or shoring and without interruption to traffic over the structure. This method, if properly executed, will prolong the life of such structures and result in substantial savings to owners.

I have also successfully reinforced several riveted bridges by adding sections to various members where required to bring them up to present-day requirements. This work has been carried out without interruption to traffic and without the necessity of any false work or underpinning to the entire satisfaction of the railroad engineers. The methods employed in this work do not differ materially from those employed on other structures.

There are numerous old highway and railroad pin-connected bridges in the United States which can be strengthened and brought up to present-day requirements by the above methods. These bridges have, up to the present time, been removed and replaced by new structures requiring the expenditure of large sums of money and, because of the necessity of removing old bridges and erecting temporary detour bridges, resultant hardships have been inflicted upon railway and highway users. Repairs by the methods outlined above can be carried out without detouring traffic unless the necessity of removing floors arises from some other reasons than strengthening of trusses.

The methods of making bridge repairs outlined above* which are more economical than the old methods of riveting are illustrated in the photographs. They have proved very successful and resulted in savings of from 25 to 80% over other known methods. However, I do not claim that we shall dispense with rivets entirely for there are instances where riveted joints are more desirable than welded joints.

Although welding is comparatively new, we will all eventually be compelled to recognize its many advantages and adapt ourselves to its use.

There are thousands of bridges scattered over our states in which only a few members are weak or corroded while others are adequate to withstand the loads applied upon them. Why discard these structures when these economical methods will restore them to present-day requirements at reasonable cost with a resultant saving in capital invested of many thousands of dollars?

* Patents pending.

Significant Diesel Repairs

By **D. R. PRATT**

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TWO different types of repair recently carried out on heavy diesel engines illustrates in a vivid manner the remarkable versatility of the oxyacetylene process.

In the first case, a $6^1/_2$ in. diameter crank shaft for a large six-cylinder diesel engine locomotive used by a logging company in the Northwest broke off between the flywheel and the first throw. To replace this crank shaft would have cost the company practically $2000, not to mention the loss involved by having the locomotive out of commission until a new crank shaft could be ordered and reassembled into the machine.

An oxyacetylene service operator was called in for advice and he agreed to supervise the repair of the crank shaft by welding. In order to allow sufficient material on the end of the shaft for machining purposes, it was decided to replace the broken end with a new 7-in. diameter section.

A furnace was built up around the crank shaft and the section to be welded was heated thoroughly with two preheating burners and some charcoal. High-test steel welding rod was used, and the repair was a complete success.

The whole job did not cost more than $100 and yet it saved a $2000 replacement charge.

The second job was carried out on a 210-hp. diesel engine which was used to operate a 10-in. suction dredge

The Completed Weld on the Exhaust Chamber Saved the $2000 Castings

for a canal system. The engine also was used to operate the lighting and hoisting equipment on the dredge. This was a six-cylinder engine and there were two three-cylinder water-jacketed exhaust manifolds connected together in the center by a gasketed joint which sealed the circulation of water through the jacket.

The gasketed joint formed a constant source of trouble because, after running the engine awhile, the gasket

The Bronze-Welding Operation Being Carried Out to Seal the Connection between the Two Chambers

would invariably start to leak, permitting water to enter the cylinders, which would prevent easy starting of the motor.

After many unsuccessful attempts to keep the gasket tight, it was decided to stop this source of annoyance once and for all by bronze-welding the exhaust manifolds together at this point.

Several interesting problems in taking care of expansion and contraction were presented. Due to the water jacket, it was necessary to make two welds, one from the inside, and the other outside. The assembly could not be aligned for welding by means of bolts connecting the end flanges because this would not permit the spacing necessary to allow for contraction of the inside weld. Futhermore, it was necessary to make the inside weld by working through the exhaust ports, which, of course, precluded preheating the casting to any extent.

The problem was solved in the following way: The two cylinders were set up loosely on timbers and then carefully aligned, leaving a $^3/_{32}$-in. space between them to provide for contraction of the inside weld. Alignment and spacing were checked by means of a straight edge and a pair of dividers.

A kerosene preheating torch was used at first to warm up the casting a little and take off the chill at the point of work, but not heat it sufficiently to make work unbearable on the inside. Then the welder crawled in partially through the exhaust ports in order to do the welding on the inside first. The inside circumference was tack-welded at the bottom and on both sides about half way up and, as it was not possible to turn the casting at that time without disturbing the alignment, a strap was placed on the top on the outside to support the top quarter, giving practically a four-point tack. With this support it was possible to turn the manifold as the inside weld progressed.

When the inside weld was completed, it was found that the two sections had drawn tightly together. Before starting the outside weld, the inside weld was reheated all around with the preheater in order to expand it slightly. This tended to open the outside a little and was sufficient to permit making the bronze-weld on the outside.

About 15 lb. of the latest type bronze-welding rod was used and the whole job took altogether 3 hr. for the welding operation. The preparation before welding and the testing required another 3 hr.

A cold water test of 50 lb. per sq. in. was put on the manifold and not even a sweat showed on either the inside or outside weld.

Another interesting feature of this work was that the new bronze-welding rod used is non-fuming which made it much easier for the welder to work on the inside of the manifold without discomfort in breathing.

As these castings were worth new about $2000, it can be seen that here, too, a considerable saving was effected through the use of the oxyacetylene process.

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